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FIELD ASSESSMENT OF AIR EMISSIONS AND THEIR CONTROL AT A REFINERY LAND TREATMENT FACILITY:

VOLUME I

by

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A field assessment was performed to measure the emissions of volatile organics from a petroleum refinery landtreatment site. As part of this study, the emissions of total volatile organics from surface-applied and subsurface-injected oily sludge were measured over a five-week period. The effect of soil tilling on the emissions was also monitored.

Volatile organics emissions rates were measured using the emission isolation flux chamber method. Emission rates of carbon dioxide and methane were also measured for use in estimating biodegradation rates. Soil samples were collected during the test periods to determine soil properties, oil levels, and microbe count. Soil surface and ambient temperatures, both inside and outside the flux chambers, were measured throughout the test periods. The measured volatile organics emission rates were compared to applicable landtreatment models.

The report is in two volumes. Volume I contains the body of the report and major appendices. Volume II contains secondary appendices, including all the raw sample analysis data.

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FOREWORD

Today's rapidly developing and changing technologies and industrial products and practices frequently carry with them the increased generation of solid and hazardous wastes. These materials, if improperly dealt with, can threaten both public health and the environment. Abandoned waste sites and accidental releases of toxic and hazardous substances to the environment also have important environmental and public health implications. The Hazardous Waste Engineering Research Laboratory assists in providing an authoritative and defensible engineering basis for assessing and solving these problems. Its products support the policies, programs, and regulations of the Environmental Protection Agency, the permitting and other responsibilities of State and local governments, and the needs of both large and small businesses in handling their wastes responsibly and economically.

The subject of this report is the control of volatile organic emissions from hazardous waste treatment, storage, and disposal technologies. The results and conclusions of this report can be used to determine the technical and economic feasibility of controlling volatile organic emissions from treatment, storage, and disposal facilities (TSDFs). Those who would find this report of use include TSDF owners/operators, hazardous waste regulatory personnel, and engineers concerned with emissions from TSDFs and engineering unit operations to reduce these emissions. For further information, contact the Alternative Technologies Division, Hazardous Waste Engineering Research Laboratory, U.S. Environmental Protection Agency, Cincinnati, Ohio 45268.

Thomas R. Hauser, Director
Hazardous Waste Engineering Research Laboratory

ABSTRACT

A field assessment was performed to measure the emissions of volatile organics from a petroleum refinery land treatment site. As part of this study, the emissions of total volatile organics from surface-applied and subsurface-injected oily sludge were measured over a five-week period. The effect of soil tilling on the emissions was also monitored.

Volatile organics emissions rates were measured using the emission isolation flux chamber method. Emission rates of carbon dioxide and methane were also measured for use in estimating biodegradation rates. Soil samples were collected during the test periods to determine soil properties, oil levels, and microbe count. Soil surface and ambient temperatures, both inside and outside the flux chambers, were measured throughout the test periods.

The measured volatile organics emission rates were compared to those predicted with the Thibodeaux-Hwang land treatment model.

This report was submitted in partial fulfillment of EPA Contracts 68-02-3850 and 68-02-3994 by the Radian Corporation under the sponsorship of the U.S. Environmental Protection Agency. This report covers a period from June 1984 to July 1986, and work was completed as of September 1986.

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SECTION 1

INTRODUCTION

The U.S. Environmental Protection Agency is currently developing information to set standards as necessary to control emissions from hazardous waste treatment, storage, and disposal facilities (TSDFs). The purpose of these regulations is to protect human health and the environment from impairment by emissions of volatile compounds and particulate matter. This regulatory development is the responsibility of the Office of Air Quality Planning and Standards (OAQPS). The Hazardous Waste Engineering Research Laboratory (HWERL) has the responsibility of providing technical support to OAQPS in the area of atmospheric emissions from hazardous waste management.

Radian Corporation is under contract (EPA Contract 68-02-3850, Work Assignment 10) to the Hazardous Waste Engineering Research Laboratory of the U.S. Environmental Protection Agency (EPA), to provide technical support in assessing the effectiveness of control techniques currently in use at hazardous waste TSDFs to reduce volatile organic emissions to the atmosphere. In the current study, volatile organics are assumed to be any compound detected by GC using a purge and trap technique. The technique is described in Section 5 of this report.

Under Work Assignment 10, Radian identified candidate TSDFs which now use one or more control techniques in order to reduce volatile organics emissions. A major part of this program involved obtaining field measurements of uncontrolled and controlled volatile organics emissions and control equipment operating information from operators of selected TSDFs. These data will be used to determine control efficiencies, costs, and typical operating procedures which could be expected at other TSDFs should such controls be implemented in the future.

In the current study, the performance of surface versus subsurface injection of waste at land treatment sites was tested and the results have increased the understanding of volatile organics emissions from land treatment disposal facilities. Subsurface injection at land treatment sites was selected for this study because it is believed to represent a major potential type of land treatment volatile organics emission control at TSDFs.

PROJECT OBJECTIVE

The objective of this program is to obtain field measurements on the effectiveness of emission controls currently in use at TSDFs. The major objectives for this particular site include the following:

- Determine the percentage of volatilized organics as a function of the applied purgeable organics and of the applied oil;
- Estimate the emissions of applied volatile organics from the test plots for the five-week testing period and annually for the entire land treatment facility;
- Determine the effectiveness of subsurface injection in reducing VOC emissions from land treatments by comparing the measured emission rates from the two application methods;
- Determine the extent of oil degradation and/or measurable biological activity;
- Determine the effects that various environmental and operational parameters have on emission rates and emission rate measurements, including those due to the emission measurement procedure; and
- Compare the measured emission rates to those calculated using the Thibodeaux-Hwang predictive emission model.

SITE DESCRIPTION

The TSDF site chosen for examination in this study is located at the Chevron, USA Refinery in El Segundo, California. The facility is a commercial crude oil refinery producing a variety of hydrocarbon products. The wastewater treatment and other oily sludges generated from these operations result in a hazardous waste. These sludges are applied to a land treatment area operated on the site. The emissions control at this site involves applying the waste by subsurface injection, rather than surface spreading, to reduce volatilization of organic compounds in the sludge.

TESTING PROGRAM

Emission measurements were performed at the Chevron facility during three one-week periods between October 9 and November 12 of 1984. Three plots were laid out on the land treatment area. Waste was applied to the surface of one plot, applied by subsurface injection to the second plot, and the third plot served as the background or control plot. The plots were then managed by a Chevron land treatment contractor following a schedule which is typical for this land treatment facility. Management involved periodic tilling and irrigation of the plots. The plots are tilled frequently to aerate the soil and provide oxygen to support aerobic biological degradation and to minimize anaerobic degradation with resulting odors. Emission measurements were made repeatedly for each plot using the flux chamber technique. Testing was conducted by Radian Corporation under the direction of Bart Eklund and Dr. Robert Wetherold. Representatives from the Environmental Protection Agency and Chevron, USA observed the testing.

Chevron performed some sampling and analyses during the test period. In particular, they measured soil surface temperatures, ambient temperatures, soil moisture content, and oil content of sludge and soil samples. In their analyses of the oil content of sludge and soil samples, Chevron used an analytical technique which they had recently developed specifically for this objective. This technique is called the modified oven drying technique (MODT), and a description of this procedure is provided in Appendix P. This technique has not yet been published nor critiqued in the open literature.

Chevron supplied results of their analyses which indicated greater accuracy and precision in determining oil content of soil samples than the standard methods employed by Radian. Also, Chevron analyzed more soil samples than Radian. The body of this report was prepared using Radian data since Radian had no way of validating Chevron's data. However, Chevron's data are included in Appendix A, along with a brief discussion and analysis. Some conclusions appear to be evident from the Chevron data which were not apparent when analyzing the Radian data. These conclusions are also included in Appendix A.

The following sections discuss the results of the testing and also the emission modeling work. Section 2 presents a summary of the results. Section 3 provides a site description, Section 4 lists the experimental approach, and Section 5 gives the sampling and analytical procedures. Section 6 provides complete summaries of the test results. Section 7 contains a description of the statistical approach used in interpreting the test data. The results of the testing are summarized and discussed in Section 8, and the measured and predicted emission rates are compared in Section 9. Finally, Section 10 discusses QA/QC and data quality. Appendices include all supporting information for the report. Appendices A-H are contained at the end of this volume and the remainder are collected as Volume 2 of this report.

UNCERTAINTIES

The variability of much of the data and many of the results is expressed, within this report, in terms of various statistical parameters. For convenience, these parameters are defined below.

- Relative Standard Deviation (RSD)--a measure of relative dispersion (precision) calculated as the standard deviation of a set of values divided by the average of these values and multiplied by one hundred to give a percentage value. The standard deviation is a measure of the dispersion about the average of the set of values. The relative standard deviation is the same as the coefficient of variation (CV).

- Standard Error (SE)--a measure of dispersion of the reported value. It is calculated as the standard deviation divided by the square root of the sample size (n) and multiplied by 100 to express the results as a percentage.

- Relative Standard Error (RSE)--a measure of the relative dispersion of the reported value. The relative standard error signifies the relative standard deviation of the reported value itself, rather than the relative standard deviation of a single determination (unless, of course, the reported value is simply the result of a single determination). The relative standard error of the mean is calculated as the standard error divided by the mean.

- 95% Confidence Interval (CI)--a value interval that has a 95% probability (confidence coefficient) of including some defined parameter of the population. The bounds of the intervals are called confidence limits or confidence bounds.

SECTION 2

CONCLUSIONS

The following site-specific findings and conclusions were obtained from the results of this study. Where appropriate, the quantitative and qualitative uncertainties associated with these findings are provided.

TOTAL VOLATILE ORGANIC EMISSION RATES

The average emission rates for each plot over the five-week test period were determined to be 47.1 [RSD (relative standard deviation) = ±14.9%], 6.16 (RSD = ±10.6%), and 53.9 (RSD = ±16.3%) ug/m^2-s of volatile organics for the surface application (Plot A), background (Plot B), and subsurface application (Plot C) plots, respectively. The instantaneous emissions from each of the three plots were as high as 370.7, 38.5, and 324.9 ug/m^2-sec, respectively.

The emission rate was found to decrease approximately exponentially with time after application for each plot. Comparing the average measured emission rate for the first week of sampling to the third and fifth (final) weeks of sampling, the emission rates decreased 93% [90.1 (RSD = 98%) to 6.58 (RSD = 89.2%) ug/m^2-s], 86% [9.38 (RSD = 88.6%) to 2.23 (RSD = 75.8%) ug/m^2-s], and 91% [103 (RSD = 115%) to 9.27 (RSD = 66.8%) ug/m^2-s] for the surface application, background, and subsurface application plots, respectively.

The five-week estimated cumulative emissions for Plots A, B, and C were 33.3, 5.2, and 39.0 kg, respectively. Assuming equal application of waste to Plots A and C, it was estimated that the ratio of volatile organics emitted over five weeks to purgeable organics in the waste was 0.30 for Plot A and 0.36 for Plot C. The ratio of volatile organics emitted over five weeks to the mass of applied oil was estimated to be 0.012 for Plot A and 0.014 for Plot C.

The measured emission rates were found to be related to the ambient air temperature above the soil surface. This resulted in a significant diurnal effect in emissions. For the two occasions when sampling was conducted before dawn, the average measured emission rate for that "half-day" (i.e., four-hour) period was lower than the average of the half-day averages for that week for each plot. For Week 1, the decrease was 75% (22.5 vs. 90.0 ug/m^2-s), 56% (4.09 vs. 9.37 ug/m^2-s), and 87% (13.8 vs. 103 ug/m^2-s) for Plots A, B, and C, respectively. For the second week of sampling, the decrease was 75% (6.41 vs. 25.2 ug/m^2-s), 54% (2.04 vs. 4.39 ug/m^2-s), and 59% (12.1 vs. 29.4 ug/m^2-s) for Plots A, B, and C, respectively.

SUBSURFACE INJECTION AS AN EMISSIONS CONTROL TECHNIQUE

This study did not find very large differences between emissions from the plots where two different sludge application techniques were used. At Chevron, subsurface application included soil tilling. Tilling was also performed on the soil periodically starting two to three days later. Immediately after sludge application, the cumulative two-day measured emissions from the surface application plot [2.63 (RSD = 17.5%) kg] were slightly greater than those from the subsurface application plot [2.07 (RSD = 16.7%) kg]. After the first tilling episode (two days after the initial application), the cumulative measured emissions appeared to be slightly greater for the subsurface application plot throughout the remainder of the test period. The total cumulative measured emissions were 14% greater from Plot C than Plot A [6.00 (RSD = 10.6%) and 5.16 (RSD = 10.6%) kg], respectively. Similarly, the estimated total emissions from Plot C (39.0 kg) were 17% greater than the total for Plot A (33.3 kg) for the five-week test period. Since the difference between total emissions from the plot were comparable to the uncertainty in emissions measurements, emissions from the two plots are essentially equal to within experimental error.

This conclusion about the effects of sludge application technique on emissions rate is expected to be limited to refineries using very simialar techniques. Sludge application techniques vary with refinery and this could affect the relative amount of emissions resulting from surface versus subsurface sludge application. In particular, if subsurface sludge application does not include tilling, significant volatile organic emission reductions might result during the period immediately following application due to the reduced soil-to-air interface.

EMISSIONS OF INDIVIDUAL COMPOUNDS

The dozen individual compounds examined behaved in the same manner as the total volatile organics. The emission rates decreased with time, increased after tilling, and showed diurnal fluctuations. The application method had a greater effect on the individual compounds than for total volatile organics. The subsurface application plot averaged 44% (RSD = 36.3%) greater emissions than the surface application plot for the 12 compounds, whereas the total volatile organics only exhibited a 14% difference. Also, a greater percentage of the applied individual compounds was emitted than for total volatile organics. For Plots A and C, the measured emissions of volatile organics were 4.7 and 5.5% of the applied material and the estimated total emissions were 30.3 and 35.5% of the applied material. For the average of the 12 compounds for Plots A and C, the measured emissions of volatile organics were 8.70% (RSD = 97.5%) and 13.4% (RSD = 77.6%), and the estimated total emissions were 44.1% (RSD = 37.0%) and 62.9% (RSD = 42.4%), respectively, of the applied material. The difference between the average emissions values and those of the 12 selected compounds is thought to be due to the differences in volatilities of the 12 selected compounds and the average volatility of the oily sludge.

BIODEGRADATION AND OIL DISAPPEARANCE

Radian measurements indicated that little or no biodegradation of the applied oil was observed. No methane was detected, implying that no anaerobic degradation occurred. Significant quantities of possible products of partial degradation were not detected. Because of the scatter in the data, neither a change in microbial population levels nor a decrease in oil content in the soil could be discerned. The measured carbon dioxide (CO_2) values were at near background levels. Assuming all CO_2 measured was due to complete aerobic degradation, less than 3% of the applied oil was completely degraded over the five-week test period.

Chevron analyzed more soil samples using a recently developed analytical technique. One or both of these factors contribute to more precise measurement of the variation of oil content with time (Appendix A). The Chevron results appear to indicate a decrease in oil levels in the soil. However, the data are quite scattered; only one of the four monitored points shows a decrease which has greater than a 95% certainty of being greater than zero.

EMISSIONS MODEL

The Thibodeaux-Hwang model for land treatment facilities was found to predict mean emission rates that were generally higher than those actually observed, but which agreed to within an order of magnitude. The model results contain a large degree of uncertainty.

SAMPLING AND ANALYTICAL VARIABILITY

The sampling and analytical variability was generally within the study objectives. Two problem areas were noted: the precision of the gas chromatography analyses of the sludge samples was ±59% vs. the program objective of ±30%, and the variability of the microbe counts was large (RSD = 82.4%, 114%, and 86.7% for Plots A, B, and C, respectively). The analytical procedure for sludge samples was modified to include a larger sample size and a more random sample aliquot selection process. The microbe count procedure proved insufficiently precise for the purposes of this study. The remaining sampling and analytical procedures are considered adequate based on the results of this study.

SECTION 3

DESCRIPTION OF TEST SITE

Chevron operates a land treatment area for the disposal of oily refinery sludge from operations at their El Segundo, California refinery. The land treatment area was started in 1979 utilizing a 20,235 m^2 (5-acre) parcel and was expanded to a 40,470 m^2 (10-acre) land treatment facility in early 1982. A site map is shown in Figure 1. The site was undergoing recuperation from overloading (since June 1984) when the oil content in the soil ranged up to 11-12%. Oil overloading generated a clay-like soil condition in some areas of the land treatment area and prevented aerobic activities resulting in a lack of biodegradation. Recuperation activities include continuous tilling and watering.

OPERATION OF CHEVRON LANDTREATMENT FACILITY

Waste oily sludge from refinery operations is collected and transported in tank trucks to the land treatment area, where it may be either applied immediately or stored for later application. Oily waste may be stored for later application in a 2,000-barrel capacity tank at the land treatment site.

Waste is applied subsurface using a 50-barrel capacity AG-GATOR injector truck equipped with four injectors, 0.46 m (18 inches) apart. The waste is injected 0.15-0.28 m (6-11 inches) below the surface and immediately disked by a disk unit pulled by the AG-GATOR unit. The freshly applied area is then rototilled and/or disked 2-3 times/week until the next sludge application. The waste oil consists of 50-75% DAF/API float, 20-30% separator cleanings, and about 5% miscellaneous oily waste. Typical sludge composition is 76% water, 12% solids, and 12% oil. The application rate is about 3,000-10,000 tons/year. The land treatment site has only been fertilized twice in five years (with potassium) and is believed to be a "rich" site, i.e., having good biological activity due to soil and climate conditions. The land treatment facility is utilized approximately 8 months of the year since the soil is too wet to cultivate during the rainy season (December through March).

The three test plots were adjacent to one another, and each plot was 27.7 m (91 ft) long and 15.2 m (50 ft) wide. According to the facility staff, the particular area in which the plots were located had not experienced oil overloading. Sludge had last been applied to the test plot area in June, 1984.

The center test plot (Plot B) was used as the "control" plot, i.e., no waste was applied during the test period. At the start of the test period (10 October 1984), Chevron applied sludge to the other two test plots. The total waste applied to the two test plots was approximately 2.8×10^4 Kg.

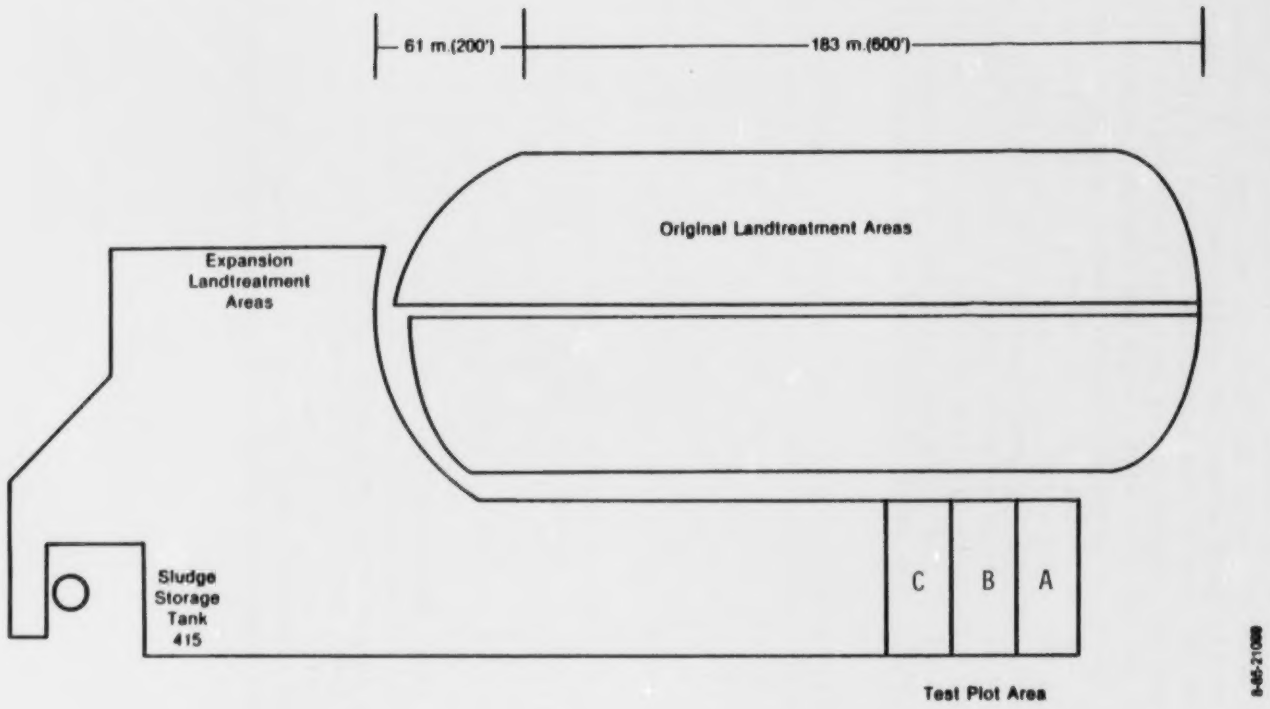
61 m.(200')
183 m.(600')
Original Landtreatment Areas
Expansion Landtreatment Areas
Sludge Storage Tank 415
C
B
A
Test Plot Area
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Figure 1. Chevron land treatment plot map.

A spreading pattern was chosen to minimize any inhomogeneities in the sludge. The trucks started in a corner of subsurface application plot (Plot C) farthest from the other plots. They proceeded across the subsurface plot, Plot B (with no sludge application) and then the surface application plot (Plot A), swung around and applied additional sludge while proceeding back to the far side of the subsurface application plot. This procedure was continued for several passes back and forth until the truck was empty. The truck was refilled with sludge and this back-and-forth pattern was repeated again to spread the second load of sludge on the remaining surfaces of the two plots. In this manner, it was believed that any inhomogeneities in the waste which could have influenced waste spreading rate would be minimized, because any gradations in waste composition due to settling in the trucks would be balanced by always starting and ending on Plot C. Similarly, variations in oil (and thus VO) content of the waste should have been balanced out, with the most oily and least oily portions of the waste applied to Plot C and waste of intermediate oil content applied to Plot A.

Chevron also tilled each plot 2-3 times per week (in addition to the tilling immediately following sludge application) during the entire five-week test period (10 October - 12 November 1984). This tilling schedule was typical for this facility. The tilling schedule during the test period is given in Table 1. The plots were irrigated with water once between the first and second sampling periods (10-13 October and 23-26 October, respectively) and three times between the second and third (9-12 November) sampling periods.

Very few refineries apply sludge by subsurface injection. Thus, it is difficult to define "typical" subsurface operation. Chevron applies sludge at a rate that normally results in oil concentrations of 5 to 7 percent oil in the soil. The annual oil loading is in the range of 8-27 kg/m_2 (300-1,000 tons of wastes per acre at 12% oil). These application rates are considerably higher (by a factor of 2-10) than rates more typically reported at refinery land treatment sites (1). According to Chevron, they utilize a higher-than-normal tilling rate for the purpose of achieving a high rate of oil reduction in the soil. Tilling is performed on a daily basis (5 days per week) on some area of the land treatment facility. This practice results in each segment of the land treatment site being tilled every 2-3 days (or 2-3 times per week). For many refinery land treatment sites tilling is performed once per application (1), although there are some sites where is is performed more frequently.

TABLE 1. TILLING SCHEDULE FOR CHEVRON LAND TREATMENT - TEST STUDY

Date	Tilling Time	Hours from Start[a]	Activity
10-10-84	0950-1030	0	Apply waste and till
10-12-84	1224-1258	50.5	Till
10-15-84	0930-1100	120.5	Till and irrigate
10-16-84	1300-1400	147.5	Till
10-18-84	0800-0930	191	Till
10-19-84	1300-1430	220	Till
10-24-84	1222-1235	338.5	Till
10-26-84	1218-1233	386.5	Till
10-29-84	0815-0930	455	Till
10-30-84	0900-1100	480	Till and irrigate
10-31-84	1000-1100	504.5	Till
11-01-84	0900-1100	528	Till and irrigate
11-02-84	0900-1030	552	Till
11-05-84	1300-1430	628	Till and irrigate
11-09-84	1225-1245	722.5	Till
11-12-84	1047-1110	793	Till

[a] Rounded off to nearest 1/2 hour.

SECTION 4

EXPERIMENTAL APPROACH

This section presents the sampling and analytical objectives of the program and the experimental design developed to meet these objectives.

SELECTION OF PROCESS/OPERATING PARAMETERS

Prior to the first sampling effort, the following program objectives were selected:

- Determine the overall daily emission rate for each plot;
- Quantify the change in emissions with time over the course of testing;
- Determine the effect of the application method on VOC emissions for weekly and annual periods;
- Estimate the biodegradation rates for each plot;
- Evaluate the effect of diurnal temperature fluctuations on emission rates;
- Determine the effect of tilling on the emissions of volatile organics;
- Examine the above factors with respect to individual components of the applied wastes;
- Compare measured and predicted emission rates from existent models; and
- Determine the sampling and analytical variability and maintain the variability within acceptable ranges.

Based upon an examination of Radian's previous land treatment studies, the relevant open literature, and the best available land treatment emission models, a list of process and operating parameters that would provide inputs to meeting the program objectives was developed. This list is given in Table 2, along with the sampling activity required.

TABLE 2. SUMMARY OF SAMPLING ACTIVITIES FOR LAND TREATMENT FACILITIES

Parameter (Symbol)	Type of Sampling Activity				
	Sample Type	Analysis	Measurement	Observation	Records
Soil temperature profile (0.05, 0.10, 0.15, 0.20 m) (2, 4, 6, 8")			Thermocouple		
Soil porosity (E)	Solid	Gravimetric/ volumetric			
Soil bulk density (B)	Solid	Gravimetric/ volumetric	Sand cone method ASTM D1556		
Particle density (e)	Solid	Specific gravity ASTM D854			
Depth of plow slice (h_p)			Tape		Operational records
Time after application (t)				Field observation	Operational records
Surface area application (A)					Site specifications
Depth of subsurface injection (h_s)				Field observation	Operational records
Atmospheric pressure			Barometer		
Air temperature			Thermocouple		

(Continued)

TABLE 2. (Continued)

Parameter (Symbol)	Type of Sampling Activity				
	Sample Type	Analysis	Measurement	Observation	Records
Relative humidity			Assman psychrometer		
Wind speed			Cup anemometer		
Direct emissions	Air (canister)	GC FID/PID	Enclosure measurement		
	Real time analysis	Real time analysis			
	Syringe	GC/FID			
Height of wetted soil remaining after partial drying				Field observation	
Solar insolation				Observation	
Soil type classification					Site description
Permeability	Solid	Falling head EM 10-2-1906			

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[a] If homogeneous waste.

EXPERIMENTAL DESIGN

The experimental design for this study was selected to obtain sufficient data to meet the objectives enumerated above. The primary emphasis of the program was on obtaining volatile organics emission measurements. The design used was a synthesis of two sampling strategies for obtaining emission measurements: totally randomized sampling, and semi-continuous sampling at a single location. Each strategy is described below.

Randomized Sampling

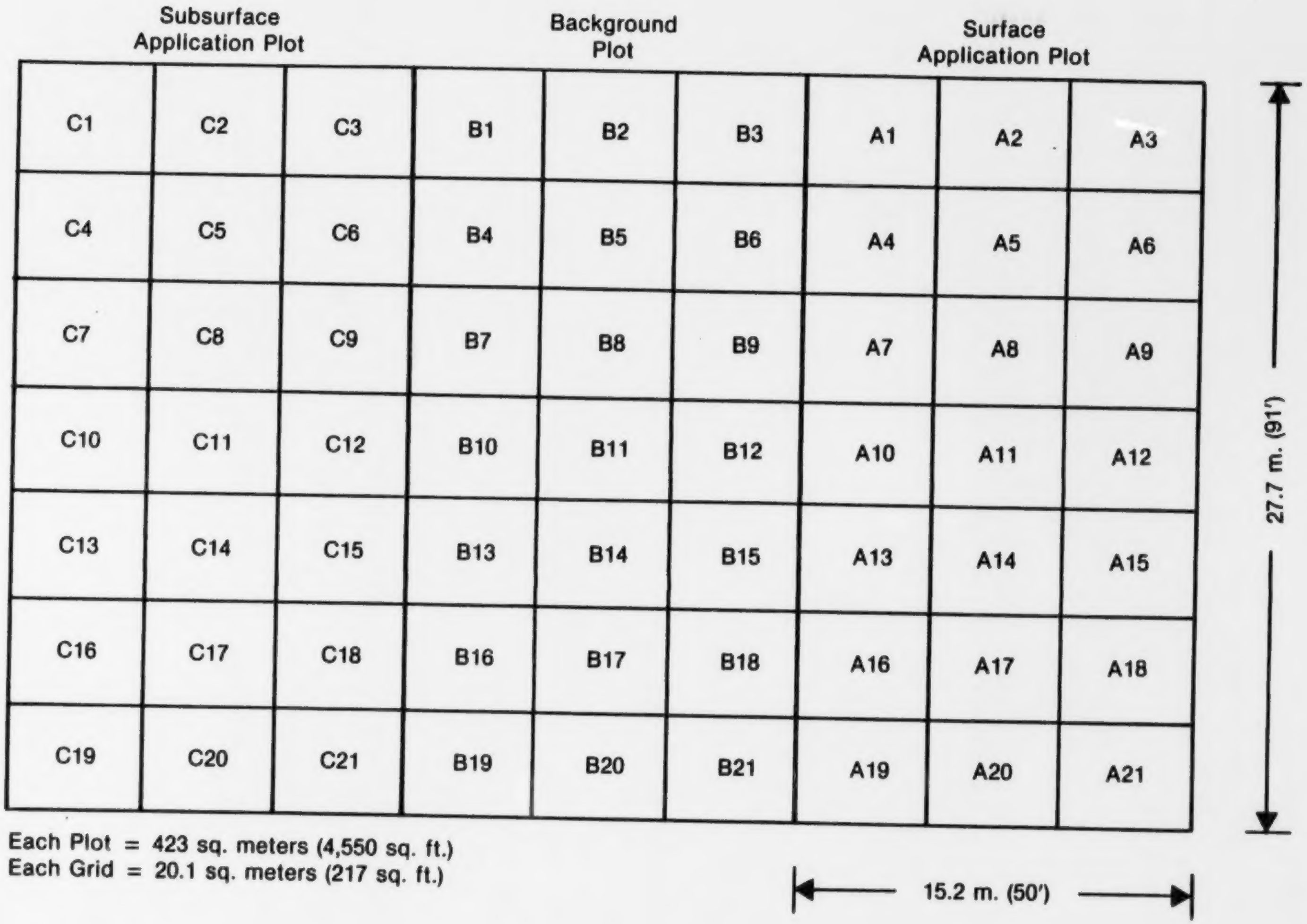
An individual emission rate measurement provides a quantitative measure for the surface area tested. In order to provide an overall estimate of the emission rate for a total plot area, a number of measurements at randomly selected points need to be performed. A statistically unbiased sample set is usually achieved by some form of random sampling in which every location in the total site area has a theoretically equal chance of being sampled. One method of selecting random samples is to divide the population into segments (i.e., total source area or zone) using an imaginery grid, assign a series of consecutive numbers to the units of the grid and select grid units to be sampled through use of a random numbers table. Increasing the number of samples taken from the site area decreases both random and systematic error associated with the estimate of the mean emission rate.

Semi-Continuous Sampling

One of the objectives of this program was to examine the change in emissions over time after application of fresh waste. The optimal sampling strategy for this objective would have been to sample a limited number of points repeatedly. Continuous sampling at a given point is normally avoided to prevent the measurement process from unduly influencing the measurements due to radiation shielding, temperature, or pressure differentials, etc. This sampling approach is also the optimal one for assessing the emission rate variability due to temporal effects (e.g., temperature).

APPLICATION OF EXPERIMENTAL DESIGN TO FIELD TESTING

The grid system used at the landfarm is depicted in Figure 2. The gridded area was made smaller than the area of applied waste to avoid non-uniform loading, i.e., to avoid sampling at the fringes of the application area. An example sampling schedule is given in Table 3. The table was derived as follows. Each sampling day was divided into two parts. During each half day, one sampling crew made measurements at the surface applied plot and the other crew at the subsurface applied plot. Each crew performed emission rate measurements at two separate control points in each plot, two randomly selected points in the plot, and one randomly selected point in the background plot. Random number tables were used to select the order of sampling, the crew used on each plot, and the equipment set each crew used. The sampling order for composite soils, soil cores, evacuated gas canisters, and their associated duplicates within a given plot were also randomly selected. A typical order is shown in Table 3.



Subsurface Application Plot			Background Plot			Surface Application Plot		
C1	C2	C3	B1	B2	B3	A1	A2	A3
C4	C5	C6	B4	B5	B6	A4	A5	A6
C7	C8	C9	B7	B8	B9	A7	A8	A9
C10	C11	C12	B10	B11	B12	A10	A11	A12
C13	C14	C15	B13	B14	B15	A13	A14	A15
C16	C17	C18	B16	B17	B18	A16	A17	A18
C19	C20	C21	B19	B20	B21	A19	A20	A21

Each Plot = 423 sq. meters (4,550 sq. ft.)
Each Grid = 20.1 sq. meters (217 sq. ft.)

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Figure 2. Test plot grid assignment.

TABLE 3. TYPICAL DAILY SAMPLING SCHEDULE

		Flux Chamber Sampling		Samples Collected			
Approximate Time	Grid Point[a]	Crew ID	F/C ID[b]	Canister	Soil	Syringe	Comments
TEST PLOT A DATE: 11/09/84 APPLICATION METHOD: SURFACE							
0800	---	002	003	-	-	X	QC
0845	A07[c]	002	003	-	X	X	
0930	B03	002	003		X	XX	
1015	A05	002	003	-	-	X	
1100	A19	002	003	X	X	X	
1145	A01	002	003	-	-	X	
1230	---	002	003	-	-	-	Till
1400	A07[c]	002	003	X	-	X	
1445	A19	002	003	X	-	X	
1530	B14	002	003	X	-	X	
TEST PLOT C DATE: 11/09/84 APPLICATION METHOD: SUBSURFACE							
0800	---	001	002	-	-	X	QC
0845	C11[c]	001	002	X	X	X	
0930	C13	001	002	-	-	X	
1015	C14	001	002	-	-	X	
1100	C15	001	002	-	-	XX	
1145	B15	001	002	-	-	X	
1230	---	001	002	-	-	-	Till
1315	C15	001	002	X	-	X	
1400	C11[c]	001	002	-	-	X	
1445	C04	001	002	-	X	X	
1530	C06	001	002	X	X	X	
1615	B03	001	002	-	-	X	

[a] Prefix A, B, C refers to plot A (surface applied), plot B (background or control plot), and plot C (subsurface applied).
[b] F/C = flux chamber
[c] Control points

Sampling was performed over four-day intervals during each of three separate sampling periods; October 9-13, October 23-26, and November 8-12 of 1984.

SECTION 5

SAMPLING AND ANALYTICAL PROCEDURES

The sampling and analytical procedures followed for the Chevron site investigation are described in this section. The discussion includes gas sample collection, solid and liquid sample collection, temperature monitoring, and the analytical techniques used on and off site. For a more detailed discussion of these topics, see the draft test plan for this testing (2).

SAMPLING PROCEDURES

Emissions Measurements with Flux Chamber

The main sampling technique employed at this site was the emission isolation flux chamber technique which involves making a direct determination of emissions. Syringe and gas canister samples were collected from the exit lines of the flux chambers for organic species analyses. In addition, air and soil temperatures were monitored throughout the sampling. Each of these sampling procedures are discussed in turn below.

Emission Isolation Flux Chamber Measurement Technique--

The emission isolation flux chamber is a device used to make a direct emission measurement. The enclosure emission measurement approach has been used by researchers to measure emission fluxes of sulfur and volatile organic species (3,4,5). The approach uses an enclosure device referred to as an emission isolation flux chamber that samples gaseous emissions from a defined surface area. Clean, dry sweep air is added to the chamber at a fixed, controlled rate. The volumetric flow rate of sweep air through the chamber is recorded and the concentration of the species of interest is measured at the exit of the chamber. The emission rate of the species is then calculated as:

$$E.R._i = \frac{(C_i)\ (Q)}{A} \tag{1}$$

where, $E.R._i$ = emission rate of species i, ug/m^2-min
C_i = measured concentration of species i, ug/m^3
Q = sweep air flow rate, m^3/min
A = exposed surface area, m^2

The flux chamber encloses a surface area of 0.13 m^2 and has a volume of 0.031 m^3. The sweep air flow rate used was 0.005 m^3/min except on 11-10-84 when a flow rate of 0.003 m^3/min was used. The lower flow rate was used in an effort to increase the sensitivity of the technique at a time when very low emission rates were being measured. The enclosure technique is currently being developed as a standard method for the quantitation of gaseous emission rates from soil surfaces (6).

A diagram of the flux chamber apparatus used for measuring emissions from the land treatment area at the El Segundo site is shown in Figure 3. The sampling equipment consisted of a stainless steel/acrylic chamber with impeller, ultra-high purity sweep air and rotameter for measuring flow into the chamber, and a sampling manifold for monitoring and/or collection of the species of interest. Concentrations of total hydrocarbons were monitored continuously in the chamber outlet gas stream using portable flame ionization detector (FID)- and/or photoionization detector (PID)-based analyzers. In addition, samples were collected for subsequent gas chromatographic (GC) analysis using both gas-tight syringes (on-site analysis) and evacuated stainless steel canisters (off-site analysis) as described below. Air and soil temperatures were measured using thermocouples.

Procedures for making the flux chamber measurements were as described in the draft method (6) except for the sampling strategy employed. As described in Section 4, two flux chambers were used simultaneously. Eight measurements on a waste-applied plot and two on the background plot were made daily with each flux chamber. Two points on the surface application plot and two on the subsurface application plot were selected as control points and sampled twice each day to define temporal variability. On-site THC and CO_2 analyses were performed for all flux chamber measurements, and several canister samples were collected daily from each plot to allow off-site detailed GC analysis. Prior to using the chamber, blank data were obtained daily.

Gas Sample Collection for On-Site Analyses--

Gas-tight syringes were used to collect gas samples for analysis on site using a Byron THC analyzer. The syringes were 100 cc volume, constructed of glass and teflon, and protected from sunlight. The syringes were flushed 3-4 times with UHP air after sample injection; the syringes were then filled 3-4 times with sample before final sample collection to minimize any cross-contamination of samples. The sampling rate was approximately 100 mL/min to avoid water or organic compound condensation in the syringes. Samples were normally analyzed within 60 minutes of collection.

Gas Sample Collection for Off-Site Analyses--

Evacuated stainless steel canisters were used to collect gas samples for shipment to Radian's Austin laboratories for detailed GC analysis. The canisters were cleaned and evacuated in Austin and sent to the field. The canister sampling consisted of attaching the canister to the flux chamber exit gas line after steady-state emissions were observed and allowing gas collection to occur for approximately one minute. Following sample collection, the canisters were shipped back to Radian's laboratories for analysis. The relative pressure in the canisters was measured in the field both before and after sampling and upon receipt in Austin to determine if any leakage had occurred. The canisters were then pressurized to 10-15 psig with UHP

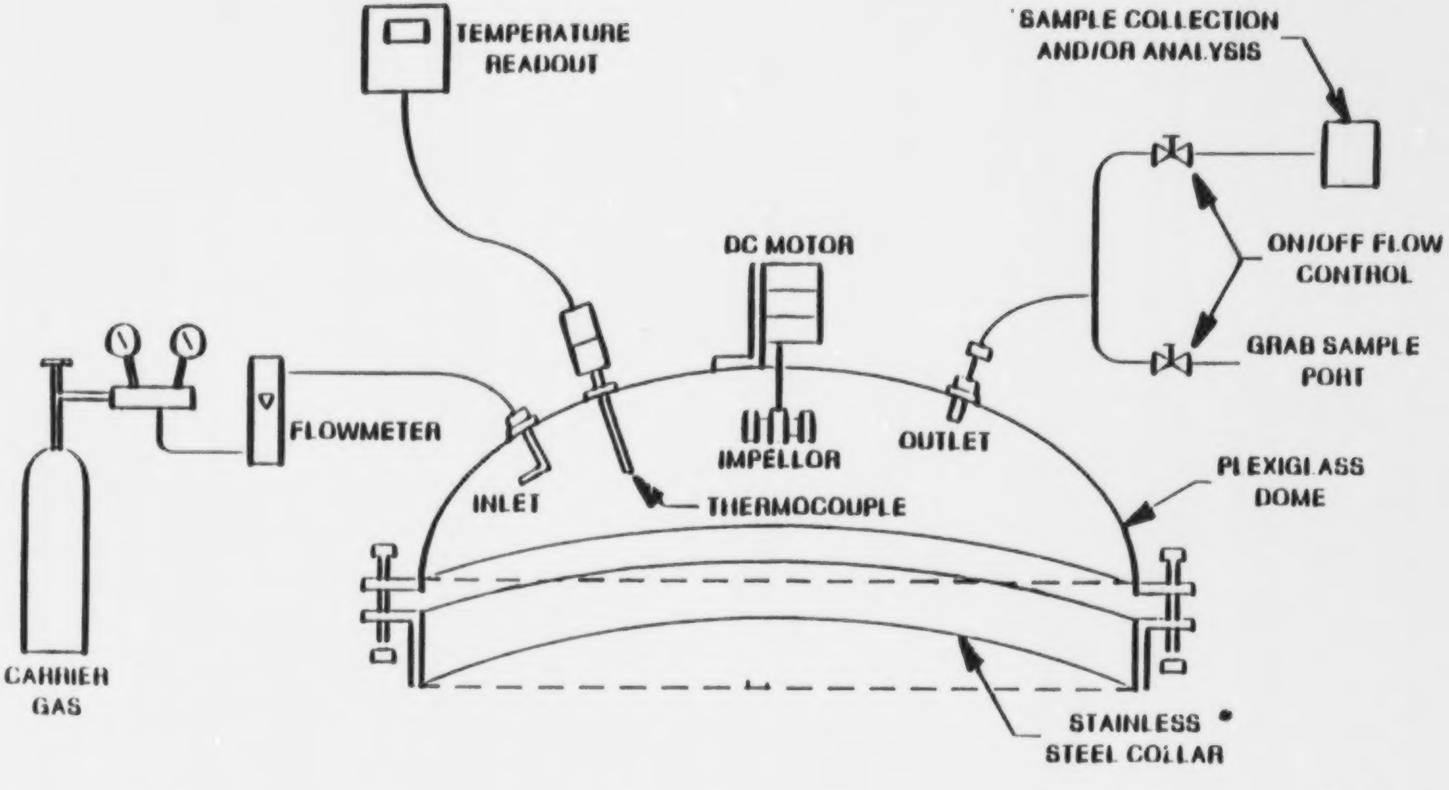
TEMPERATURE READOUT
SAMPLE COLLECTION AND/OR ANALYSIS
DC MOTOR
ON/OFF FLOW CONTROL
GRAB SAMPLE PORT
FLOWMETER
INLET
THERMOCOUPLE
IMPELLOR
OUTLET
PLEXIGLASS DOME
CARRIER GAS
STAINLESS STEEL COLLAR
70A3404

Figure 3. Cutaway side view of emission isolation flux chamber and sampling apparatus.

nitrogen to provide positive pressure for removing the sample for analysis and to dilute oxygen and moisture in the sample to minimize sample component reactions. Canister dilution is calculated from the absolute pressure before and after sample collection, and after addition of UHP N_2.

During the first site visit, ambient air samples were collected upwind of the test plots at Chevron's request to check for possible deposition of volatile organics on the plots from other sources in the refinery. Evacuated stainless steel gas canisters were placed immediately upwind of the plots on a small berm, fitted with gas flow control devices, and allowed to collect samples for a 24-hour period.

Temperature Measurement--

Type K thermocouples were used to monitor the air and soil temperatures inside and outside of each flux chamber. The thermocouples exhibited a response time of 5-10 seconds to reach a true value. The flux chamber air temperature measurement thermocouple was mounted into the chamber top and required removal to obtain ambient air temperatures. Two separate thermocouples were used for determining soil temperatures: one inside the chamber and one outside. Each was placed into the ground to a depth of 0.013-0.019 m (1/2-3/4 in.) and soil temperatures were measured over that range. During part of the testing, a third soil thermocouple was used to measure the soil temperature outside the flux chamber. The thermocouple was placed flat against the soil surface and covered lightly with additional soil, a technique suggested by Chevron and EPA personnel.

Liquid and Solid Sampling Procedures

Liquid Sampling Procedures--

Liquid grab samples of the sludge and of the service water used to irrigate the soil were collected. Sludge from two tank trucks was transferred to the application vehicle (tractor) and applied to the soil. Each tank truck held two application tractor loads. After the first load was transferred from the tank truck to the application tractor, 4-6 sample containers were filled with sludge from the tractor. The samples were collected consecutively, while the tractor tank was full, from a gravity-fed line. While two tractor loads were required to empty each tank truck, samples were collected after only one of the two transfers from each tank truck load. One service water sample was collected from the plant service water line to determine the concentration of organics in this water which the facility applies as part of its site management technique. The samples were analyzed for volatile organic compounds and for this reason were collected in glass containers with teflon-lined caps and filled with material so that minimal headspace was present. Samples were stored at 4°C until analysis.

Solid Sampling Procedures--

Two types of solid samples were collected: soil composites and undisturbed soil cores. Soil composites were used for percent oil and grease, percent moisture, and microbe count determinations. The undisturbed soil cores were used for determining physical properties of the soil. Both types of solid samples were collected adjacent to points where flux chamber measurements were made. The composite samples were collected using a hand auger and augering to a depth of up to 0.41 m (16 in.). During the second week of sampling, this procedure was modified to collect samples no deeper than 0.25-0.30 m (10-12 in.) or until sand was encountered (i.e., to the bottom of the zone of incorporation). The soil was mixed and a representative fraction placed in a glass container with a teflon-lined cap and then stored at 4°C until analysis. The undisturbed soil cores were collected by driving an 0.47 m (18 1/2 in.) long by 0.033 m (1 5/16 in.) I.D. brass sleeve 0.2 m (8 in.) into the ground, removing the sleeve and capping both ends.

ANALYTICAL PROCEDURES

The analytical protocols for this program are divided into two general categories: on-site analyses and off-site analyses. Details for each of these categories are presented in the following subsections.

On-Site Analyses

The on-site analyses were limited to gas-phase analyses of the flux chamber exit gas for total hydrocarbons (THC), carbon dioxide (CO_2), and methane (CH_4). Portable analyzers were used for screening purposes and a Byron THC analyzer was used for quantitative results. Each type of instrument is described below.

Portable THC Analyzers--

Two types of portable THC analyzers were used to monitor the exit gas from the flux chambers and indicate when steady-state emissions had been reached. The Analytical Instrument Development, Inc. (AID) Model 580 is a battery-powered portable gas analyzer that contains a PID detector and detects THC over a range of 0-2,000 ppm with two sensitivity ranges. The instrument was calibrated with toluene diluted in UHP air. The Century organic vapor analyzer (OVA) contains an FID detector and detects THC over a range of 1-10,000 ppm. The instrument was calibrated with methane diluted in UHP air. In general, the AID instrument showed a greater response to the site emissions and was used preferentially.

On-Site Quantitative Analyzer--

A Byron Instruments Model 401 THC analyzer was used to quantitate emissions for THC, CO_2, and methane. The analyzer is essentially a dedicated gas chromatograph fitted with a flame ionization detector. The Model 401 has five output channels for monitoring total hydrocarbons, methane, non-methane hydrocarbons, carbon monoxide, and carbon dioxide. When operated in the full scan mode, a gas sample is introduced directly to the FID, yielding a THC measurement. Subsequently, a second sample is injected and nonmethane hydrocarbons (NMHC), CH_4, CO_2, and CO are chromatographically separated. One at a time, each of these groups is passed through an oxidizer/reducer to convert all carbon to CH_4. These reduced streams are then individually introduced to the FID for measurement. A complete cycle requires 12 minutes. During each analysis, a built-in integrator is first cleared and then allowed to accumulate electrical charge corresponding to the detector response. At the completion of each analysis, this accumulated charge representing the integrated area is available for data recordation.

During this program, the values of THC were considered to be more useful than NMHC values. For this reason, the instrument was not calibrated for NMHC, and the NMHC values that were obtained coincidentally with the CO_2 and methane analyses were not used.

All data from the Byron instrument were automatically captured, stored on disk, and reduced using an Apple® II microcomputer. In addition, the computer recorded data and time of analysis, instrument, analysis type, sampling location, and run number. As a backup to the microcomputer data acquisition system, integrated areas for the instrument were recorded using a stripchart recorder to provide hardcopy records of the analyses.

Off-Site Analyses

The discussion of the off-site analyses is divided into the chemical speciation of the gas canister and liquid source samples, oil and grease analyses, and determination of physical properties for the solid samples collected.

Gas Chromatographic (GC) Analyses--

Chemical speciation of air samples collected in canisters and liquid source samples was performed off site. Analysis of the various types of samples for C_2 to C_{10} hydrocarbon species took place in three steps: cryogenic concentration, gas chromatographic separation and detection, and evaluation. Liquid samples were analyzed using a purge and trap technique modified to integrate with cryogenic concentration. All data are reported as ppmv in dry air (gas samples), mg/l (liquid samples), or ug/g (solid samples) as quantitated against certified propane and hexane standards.

Throughout this report, the concentration of volatile organics in the gas samples is assumed to be equal to the concentrations detected using the purge and trap technique. The purgeable organics detected in the liquid and sludge samples were determined using the same purge and trap technique and are assumed to be equivalent to the volatile organics.

Air samples--To achieve the desired detection levels, hydrocarbon species must be separated from the ambient air matrix and concentrated. This was accomplished by pressurizing the air sample and passing it through a Perma-Pure® drying tube to remove water vapor and then through a trap cooled in liquid oxygen. A known amount of sample was desorbed directly onto the analytical columns by heating the traps and backflushing with carrier gas.

All analyses were performed on a Varian 3700 GC. Hydrocarbon species were separated on temperature-programmed, fused silica capillary columns. An FID was used to detect and quantitate hydrocarbon species. A PID was also used to provide additional qualitative information. In addition, a second sample aliquot was resolved on a separate column and analyzed by a

Hall Electrolytic Conductivity Detector (HECD) operated in the halogen mode. This provided specific detection of halogenated VOCs which may not otherwise have exhibited adequate response characteristics on the FID/PID. This GC system with multiple detectors has been previously described (7).

The FID/PID output from the gas chromatograph was processed with a Varian 401 Chromatographic Data System (CDS). The CDS provided peak areas and retention times. A second data system, Apple® II plus microcomputer, was used to identify peaks on the basis of retention times and to compute quantitative results by comparing peak areas with a previously established standard response. The second data system was also used to perform routine data checks such as resolution, calibration stability, variance in quality control standards, and blank results.

Liquid samples--All liquid samples (water and sludge) were analyzed in a purge-and-trap manner. This was accomplished by passing ultra-high purity nitrogen through the sample for 20 minutes and trapping the resultant gas mixtures in the cryogenic traps of the analytical system. The analytical procedure followed was then identical to that described above. The volume of sample used depended upon the anticipated concentration of the compounds of interest.

Gas Chromatography-Mass Spectrometry (GC/MS) Confirmation--

Confirmation of the identity of the major compounds observed in the air samples analyzed by GC were attempted using a Hewlett-Packard Model 5982 GC/MS system. The GC/MS protocol followed was equivalent to that employed on the GC. Four samples were analyzed. These samples were selected from the gas canisters collected on the basis of the component concentrations observed in the GC analyses.

Oil and Grease Analyses--

Liquid (sludge) samples--The determination of percent water, oil, and solids in the sludge was done according to a protocol supplied by Chevron at the time the test plan was developed. This method, called the "THF" method, was chosen based upon Chevron's recommendation that standard methods were less accurate for this type of sample. Oil and water in the waste are solubilized with tetrahydrofuran (THF) and separated from the insoluble solids. Residual solids are weighed, and water is determined in the THF by Karl Fischer titration. Oil is calculated by difference. This analysis technique is described in more detail in Appendix O.

Solid samples--The percent of oil and grease in the soil samples was determined by EPA Method 413.1. The samples were acidified with hydrochloric acid and serially extracted with fluorocarbon-113 in a separatory funnel. The solvent was evaporated from the extract and the residue weighed.

Bacterial Counts--

Samples collected for bacterial counts were tightly sealed and stored at 4°C until counts were ready to be performed. The bacterial counts were made using the pour plate method (Standard Methods for the Examination of

Water and Wastewater, 16th Edition, M.A.H. Franson, Editor, American Public Health Association, Washington, D.C., Method 907A). Serial dilutions were made for each sample. The dilute solutions were then spread on agar plates, stored under controlled conditions for several days, and colony counts made.

Physical Properties of Soils--

The following physical properties were determined for core samples collected at the El Segundo landfarm: bulk density, particle density, total porosity, moisture content, and particle size distribution. Each method is described in turn below.

Bulk density--Soil samples collected in undisturbed cores were used for determining bulk density (Methods of Soil Analysis, C. A. Black, Ed., American Society of Agronomy, Inc., Madison, Wisconsin (1965) page 375). The sealed core samples were carefully measured for volume determination. After recording the volume, the entire soil sample was transferred to a tared watch glass and placed in an oven at 110 ±5°C until a constant weight was obtained. The bulk density, D, is the oven dry weight, M, over the bulk volume, V_b; that is,

$$D(g/cm^3) = M/V_b \tag{2}$$

Particle density--Particle density was determined on an oven-dried sample of soil according to ASTM D854, "Standard Test Method for Specific Gravity of Soils," part 19, page 212. This method consists of placing the dried soil in a pycnometer (constant volume vessel) and filling all voids with distilled water. The particle density of the soil can be calculated based on the volume of water displaced by the soil and the dry weight of the soil. An exception to the ASTM method will be taken in reporting the results. Instead of reporting the particle density as a specific gravity, i.e., relative to water, it is reported as a mass per unit volume (g/cm^3).

Total porosity--Total porosity is a measure of the void space in undisturbed soil. Total porosity was calculated from bulk density and particle density measurements (Methods of Soil Analysis, C. A. Black, Ed., American Society of Agronomy, Inc., Madison, Wisconsin (1965) pg. 300).

The bulk density of the soil was measured on an undisturbed core as described earlier:

$$D = M/V_b \tag{3}$$

where D = bulk density (g/cm^3),
M = mass of oven dry soil (gm), and
V_b = bulk volume (cm^3).

The particle density describes the volume of soil occupied by solid particles:

$$P = M/V_p \tag{4}$$

where P = particle density (g/cm^3),
M = mass of oven dried soil (g), and
V_p = volume occupied by solid particles having a mass M (cm^3).

Therefore, the fraction of space in a soil column occupied by solid particles is V_p/V_b, and consequently, is equal to D/P. Total porosity, S_t, is then the percentage of the bulk volume not occupied by solids:

$$S_t = 100[1 - (D/P)] \tag{5}$$

Moisture content--The moisture content of a soil in large part affects the soils compaction, density, and porosity. Soil core samples were measured for moisture according to ASTM D2226, "Standard Method for Laboratory Determination of Water (Moisture) Content of Soil, Rock, and Soil-Aggregate Mixtures," part 19, page 347 (1982).

The sample was weighed and sealed in a container before placing the soil and open container in a drying oven at 110 ±5°C. The sample was dried to a constant weight. The container was then weighed empty to determine its tare weight. The moisture content, W, of the sample is calculated as follows:

$$W = [(w_1-w_2)/(w_2-w_c)] \times 100 \tag{6}$$

where W = water content (% of dry sample),
w_1 = mass of container and moist specimen (g),
w_2 = mass of container and oven dried specimen (g), and
w_c = mass of container (g).

Particle size distribution--Particle size distribution was determined by the method described in ASTM D422. This procedure consisted of a standard sieve analysis with screen openings ranging from 75 to 4750 microns in diameter. A hydrometer was used to determine particle sizes in the range between 1 and 75 microns.

SECTION 6

SAMPLING AND ANALYTICAL RESULTS

The following section presents the sampling and analytical results from the Chevron site investigation. Included are summaries of all on- and off-site analytical data and any statements necessary to qualify or limit the results. The presentation of results has been organized by sample type: gas, liquid, and soil.

GAS SAMPLES

As previously described, gas samples were collected from the outlet lines of the flux chambers for on- and off-site analyses and ambient air samples were collected for off-site analyses.

Flux Chamber Air Samples

The on-site Byron analyses are given in Table 4; also included are the average measured temperatures and the surface shading observed. No specific methane data are reported. No methane was detected for any of the syringe samples analyzed[1]. Some of the measured temperature data have been omitted due to errors caused by an incorrectly wired thermocouple readout. In addition, the Byron data for 10-26-84 and 11-08-84 to 11-10-84 are considered suspect based upon QC data. The erroneous data were probably due to moisture in the sample lines. Results of the QA/QC activities are reported in Section 10.

The results of the analysis of the gas canister samples collected from the flux chambers are given in Table 5. Duplicate samples and analyses are included. The data summary sheets for each individual analysis are given in Appendix J.

Ambient Air Samples

Ambient air samples were collected to examine the possibility of volatile organics in the air contributing to the land treatment area's oil loading and emissions through deposition on the soil. Two samples were collected and the analytical results for these samples are summarized in Table 6. The data summary sheets for each analysis are given in Appendix K. The ambient air concentrations observed are on the order of 1.5 ppm total NMHC. These low concentrations would seem to preclude ambient volatile organics being a significant contributor to either loading or emissions.

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[1] The detection limit of the Byron 401 for methane is 1.0 ppmv.

TABLE 4. RESULTS OF ON-SITE ANALYSES OF FLUX CHAMBER GAS SAMPLES

SAMPLE ID	SAMPLING LOCATION	SAMPLING DATE	SAMPLING TIME	THC (ppm)	CO2 (ppm)	CHAMBER GAS TEMP DEG C	CHAMBER SOIL TEMP DEG C	GAS CANISTER ID	OUTSIDE AIR TEMP DEG C	OUTSIDE SOIL DEG C	EPA OUT SOIL DEG C	% CHAMBER SURFACE SHADED
C001	A19	10-9-84	1245	6	224	45	29		30	33		
C006	A09	10-9-84	1420	7	104	42	31		26	31		
C010	A02	10-9-84	1620	6	280	35	33		32	31		
C020	A07	10-9-84	1810	3	72	24	26	C021	22	25		
➤ C039	A19	10-10-84	1110	597	200	32	27	C040	31	27		
C045	A20	10-10-84	1145	695	403	37	28	C046	36	28		
C048	A07	10-10-84	1245	414	307	34	28	C049	33	29		
C055	A03	10-10-84	1328	1030	91	35	31	C056	30	28		
C064	A12	10-10-84	1505	578	138	35	29		32	29		
C072	A07	10-10-84	1550	529	229	34	30	C070+71	32	25		40
	A14	10-10-84	1752			25	26	C083	26	23		
C076	A19	10-10-84	1629	208	124	32	28	C075	29	29		75
C084	A17	10-11-84	557	53	62	19	20	C085	19	21		100
C091	A13	10-11-84	641	28	133	19	20	C092	19	20		100
C097	A07	10-11-84	731	100	254	18	20	C096	18	19		
C099	A19	10-11-84	810	60	113	20	20	C100+D	20	20		
C105	A07	10-11-84	925	143	248	21	20	C104	21	20		
C112	A19	10-11-84	1007	77	142	24	22	C113	23	21		
C121	A14	10-11-84	1132	101	387	37	39		34	27		
C125	A16	10-11-84	1208	51	155	34	32		32	29		
C135	A19	10-12-84	950	78	120	35	24	C136	33	23		
	A07	10-12-84	1058			39	28	C141	30	28		
C138	A14	10-12-84	1030	69	172	38	24		34	23		
C145	A13	10-12-84	1136	37	134	41	29		35	30		
➤ C152	A07	10-12-84	1315	452	188	35	30	C153	31	27		
	A06	10-12-84	1440			35	29	C158	30	29		
C157	A19	10-12-84	1402	422	214	38	38		31	26		
C161	A12	10-12-84	1515	246	146	36	31	C162	31	29		
C174	A19	10-13-84	839	44	60	21	20		26	19		100
	A07	10-13-84	913			26	18	C175+6	21	19		100
C178	A14	10-13-84	950	132	223	32	27		29	20		90
C184	A13	10-13-84	1100	131	138	40	28		35	27		40
C186	A11	10-13-84	1142	129	95	43	33		34	36		
C192	A07	10-13-84	1352	111	307	39	34		31	38		
	A19	10-13-84	1425			39	33	C198	33	36		40
C203	A06	10-13-84	1459	184	133	40	39		33	34		30
C213	A07	10-23-84	930	77	304	25	37		23	33		100
C218	A11	10-23-84	1020	34	403	22	34		27	29		70
C223	A19	10-23-84	1104	16	138	20	29	C224	24	35		
C233	A21	10-23-84	1235	51	311	23	24	C234	29	32		10
C236	A17	10-23-84	1316	69	307	21	20		31	22	19	
C238	A15	10-23-84	1355	46	188	22	20		27	24	20	
C239	A07	10-23-84	1440	47	158	15	27		28	25	22	30
C244	A19	10-23-84	1515	18	114	17	12	C245	21	22	21	45
C254	A07	10-24-84	850	22	252			C255				100
C260	A19	10-24-84	1000	20	136			C261				95
C266	A16	10-24-84	1037	11	193							80
C269	A15	10-24-84	1112	51	138							40
➤ C271	A19	10-24-84	1306	38	239			C272				
C275	A07	10-24-84	1351	295	282							10
C281	A12	10-24-84	1455	99	124			C280				50
C283	A15	10-24-84	1532	141				C284				50

➤ = tilling.

TABLE 4. (Continued)

SAMPLE ID	SAMPLING LOCATION	SAMPLING DATE	SAMPLING TIME	THC (ppm)	CO2 (ppm)	CHAMBER GAS TEMP DEG C	CHAMBER SOIL TEMP DEG C	GAS CANISTER ID	OUTSIDE AIR TEMP DEG C	OUTSIDE SOIL DEG C	EPA OUT SOIL DEG C	% CHAMBER SURFACE SHADED
C288	A19	10-25-84	538	7	92							100
C291	A07	10-25-84	610	24	146			C292				100
C296	A17	10-25-84	654	15	86			C297				100
C305	A15	10-25-84	804	27	88							100
C309	A05	10-25-84	845	30	262			C310				100
C315	A19	10-25-84	1229	23	56							50
C318	A08	10-25-84	1300	51	135			C319				40
C323	A07	10-25-84	1402	51	157							
C330	A21	10-26-84	933	10	384	32	19		29	24	25	
C332	A07	10-26-84	1001	29	138	32	22	C331	28	26	27	
C338	A19	10-26-84	1034	2	160	37	32		32	31	32	
C340	A08	10-26-84	1103	14	160	38	24		33	32	33	
C345	A07	10-26-84	1304	3	102	36	45	C346	29	30	33	
C351	A19	10-26-84	1340	28	268	35	31	C352	32	33	31	
C357	A16	10-26-84	1410	38	312	37	35	C354	30	32	34	
C363	A17	10-26-84	1515	42	316	37	37		32	31	33	
C368	A03	11-8-84	942	4	106	29	22	C369	23	27	25	100
C370	A01	11-8-84	1017	2	249	30	24		26	21	21	100
C376	A19	11-8-84	1134	1	197	35	32	C383	30	27	23	33
C378	A07	11-8-84	1214	2	10	36	26		30	21	22	10
C382	A07	11-8-84	1244	1	68	35	28		25	22	22	25
C388	A12	11-8-84	1340	2	150	35	28	C389+90	30	26	27	
C393	A19	11-8-84	1425	0	68	31	28		27	24	24	50
C401	A18	11-8-84	1536	0	148	26	26		25	23	23	90
C406	A07	11-9-84	912	0	45	27	17		22	16	16	100
C414	A05	11-9-84	1027	2	71	35	26		31	39	38	50
C417	A19	11-9-84	1101	1	66	37	29	C418	32	28	31	50
C420	A01	11-9-84	1140	0	109	40	27		36	25	26	50
C425	A20	11-9-84	1323	0	359	31	24		26	22	22	50
C427	A07	11-9-84	1402	0	122	32	25	C428	29	26	26	50
C431	A19	11-9-84	1430	7	254	27	22	C432	27	21	21	90
C439	A12	11-9-84	1543	1	116	26	22		25	20	20	100
C442	A11	11-10-84	940	1	268	30	21	C443	23	20	18	100
C447	A07	11-10-84	1026	1	238	34	30		24	20	26	60
C451	A19	11-10-84	1114	1	158	38	41		26	37	32	50
C455	A18	11-10-84	1202	27	431	37	33		27	28	34	40
C464	A05	11-10-84	1340	32	155	38	30	C462	26	29	30	50
C466	A07	11-10-84	1430	40	370	33	27	C467+68	27	28	30	50
C473	A17	11-12-84	756	10	207	20	13			14	15	100
C477	A08	11-12-84	835	8	55	23	16	C478	19	17	17	90
C481	A07	11-12-84	906	14	217	30	17		24	19	20	90
C487	A19	11-12-84	1009	3	119	28	19	C488	25	25	25	75
C492	A07	11-12-84	1127	48	202	27	23	C493	24	22	21	100
C497	A19	11-12-84	1201	14	248	27	23	C498	21	23	23	100
C504	A21	11-12-84	1235	20	188	27	25		22	21	22	100
C509	A20	11-12-84	1338	35	224	35	23		26	28	26	90
C002	B18	10-9-84	1245	5	103	40	35		28	34		
C004	B01	10-9-84	1325	6	274	43	36		25	32		
C005	B13	10-9-84	1420	1	298	42	37		36	34		
C008	B07	10-9-84	1515	9	158	40	29		27	32		
C009	B08	10-9-84	1608	4	82	38	34		35	33		40

TABLE 4. (Continued)

SAMPLE ID	SAMPLING LOCATION	SAMPLING DATE	SAMPLING TIME	THC (ppm)	CO2 (ppm)	CHAMBER GAS TEMP DEG C	CHAMBER SOIL TEMP DEG C	GAS CANISTER ID	OUTSIDE AIR TEMP DEG C	OUTSIDE SOIL DEG C	EPA OUT SOIL DEG C	% CHAMBER SURFACE SHADED
C014	B11	10-9-84	1705	4	202	32	30	C015	28	29		
C017	B04	10-9-84	1812	3	340	23	26	C018	23	23		
C023	B01	10-9-84	1855	4	58	20	26		20	25		
➤C057	B06	10-10-84	1340	113	144	36	36		33	27		
C060	B12	10-10-84	1415	32	226	38	36		31	30		
C077	B11	10-10-84	1655	21	387	31	28		28	24		
C078	B09	10-10-84	1709	38	234	30	28		29	27		
C098	B06	10-11-84	800	13	58							
C101	B17	10-11-84	841	11	395							
C120	B15	10-11-84	1057	14	172							
C126	B11	10-11-84	1220	16	189							
C137	B09	10-12-84	1030	13	48	36	29		34	32		
C146	B16	10-12-84	1148	11	173	42	46		35	28		
➤C165	B15	10-12-84	1536	53	384	39	30	C164	31	31		
C167	B18	10-12-84	1011	27	295	28	29		26	29		
C179	B01	10-13-84	952	31	245							
C180	B02	10-13-84	1029	17	81	36	26		36	27		
C190	B13	10-13-84	1153	38	400			C189				
C209	B11	10-13-84	1545	29	182	38	33		31	31		
C219	B17	10-23-84	1033	8	318							
	B01	10-23-84	1150			24	23	C225	31	30		
C235	B03	10-23-84	1322	16	188							
C249	B07	10-23-84	1553	20	229	16	10		21	22	18	70
C257	B06	10-24-84	925	5	97							100
C270	B14	10-24-84	1123	11	110	41	31		36	36	36	
➤C277	B13	10-24-84	1410	46	251	39	29	C278	34	28	30	
C278	B18	10-24-84	1423	15	163							50
C300	B20	10-25-84	730	6	180							100
C303	B03	10-25-84	802	6	138	14	11		13	10	10	
C314	B09	10-25-84	1226	12	135	42	29		34	28	27	
C321	B01	10-25-84	1335	22	284							40
C327	B14	10-26-84	903	5	231	17	29		15	29	15	
C328	B14	10-26-84	931	8	119			C329				80
➤C361	B06	10-26-84	1443	15	445	37	27		29	29	28	
C362	B03	10-26-84	1518	6	262							40
C373	B16	11-8-84	1057	3	362	34	37		29	21	21	50
C380	B19	11-8-84	1232	0	145	33	28	C381	25	27	27	50
C397	B11	11-8-84	1500	2	131	27	24		23	22	23	50
C402	B18	11-8-84	1604	1	200	22	22		22	22	21	100
C411	B03	11-9-84	947	1	98	32	22		27	22	23	50
C421	B15	11-9-84	1140	0	95	35	28		25	32	33	50
➤C436	B14	11-9-84	1507	1	113	29	24	C437	25	23	24	100
C438	B03	11-9-84	1524	2	77	26	25		22	20	20	100
C456	B14	11-10-84	1209	10	210	40	30	C457	27	22	23	50
C459	B04	11-10-84	1248	7	193	38	29		27	31	30	40
C472	B01	11-12-84	752	3	89	18	14		17	13	13	100
C491	B15	11-12-84	1040	4	116	29	30		25	24	24	100
➤C499	B13	11-12-84	1207	22	221	28	24	C500	22	24	24	100
C506	B21	11-12-84	1306	8	171	32	31		24	26	26	50
C003	C11	10-9-84	1325	7	116							
C007	C05	10-9-84	1515	8	110							

TABLE 4. (Continued)

SAMPLE ID	SAMPLING LOCATION	SAMPLING DATE	SAMPLING TIME	THC (ppm)	CO2 (ppm)	CHAMBER GAS TEMP DEG C	CHAMBER SOIL TEMP DEG C	GAS CANISTER ID	OUTSIDE AIR TEMP DEG C	OUTSIDE SOIL DEG C	EPA OUT SOIL DEG C	% CHAMBER SURFACE SHADED
C011	C04	10-9-84	1700	4	138			C012				
C024	C01	10-9-84	1853	4	238							80
➤C037	C11	10-10-84	1105	434	191	31	27	C038	28	27		
C043	C15	10-10-84	1145	489	176	33	28	C044+D	30	25		
C050	C10	10-10-84	1255	897	133	36	33	C051	33	29		
C062	C19	10-10-84	1440	149	257	36	32	C063	34	25		
C069	C09	10-10-84	1526	271	221	35	30	C067	30	29		
C073	C11	10-10-84	1615	226	149	31	28	C074	28	29		
C079	C15	10-10-84	1733	72	84	27	25	C080	25	25		
C082	C10	10-10-84	1816	30	378	21	23		21	22		
C086	C11	10-11-84	600		205	19	20	C087	20	20		100
C089	C15	10-11-84	645	8	104	19	21	C090	21	21		100
C094	C07	10-11-84	725	36	116	19	22	C095	20	21		
C102	C09	10-11-84	845	59	91	21	20	C103	20	21		
C106	C06	10-11-84	925	84	77	22	22		22	22		
C110	C15	10-11-84	1005	16	100	24	23	C111	24	22		
	C11	10-11-84	1046			27	23	C117+8	27	21		
C122	C17	10-11-84	1134	138	146	35	26	C123	30	29		
C133	C01	10-12-84	950	299	190			C134				
C142	C11	10-12-84	1100	133	179							40
C143	C15	10-12-84	1136	18	123							
C147	C03	10-12-84	1217	743	282			C148				
➤C150	C15	10-12-84	1320	1215	378							
C151	C15	10-12-84	1320	1160	370							
	C11	10-12-84	1401					C156				
C159	C05	10-12-84	1441	416	196							
C168	C13	10-12-84	1616	499	194			C169				
C173	C01	10-13-84	831	107	180	20	17		20	17		
C177	C20	10-13-84	915	116	113	19	24		17	24		
C181	C15	10-13-84	1028	262	151	32	40	C182	31	46		
C185	C11	10-13-84	1115	256	237	33	50		35	48		
C194	C13	10-13-84	1352	181	329	20	20	C195	29	29		
C201	C02	10-13-84	1420	170	315	23	27		27	32		
C204	C11	10-13-84	1503	179	324	21	26		30	26		
C208	C15	10-13-84	1545	245	177	19	25	C207	26	24		
C215	C11	10-23-84	941	40	306			C216				
C222	C15	10-23-84	1106	24	208							
C227	C05	10-23-84	1150	44	234			C229				
C232	C02	10-23-84	1237	37	160			C231				
C237	C18	10-23-84	1404	48	160							
C241	C11	10-23-84	1438	62	250							
C247	C19	10-23-84	1515	46	262							
C248	C15	10-23-84	1553	24	207			C250				
C256	C15	10-24-84	857	20	154	27	16		25	24	20	
C258	C05	10-24-84	932	18	178	33	18		29	24	34	
C262	C11	10-24-84	1002	38	180	33	20	C263	31	23	24	
C267	C19	10-24-84	1048	38	257	39	34		36	33	35	
➤C274	C01	10-24-84	1330	487	458	34	32		32	28	28	
C282	C13	10-24-84	1451	202	323	38	35		33	38	40	
C285	C11	10-24-84	1534	216	475	42	30	C286	36	32	28	
C287	C15	10-24-84	1615	144	302	35	26		32	32	31	
C289	C11	10-25-84	540	28	176	10	12		10	12	12	100

TABLE 4. (Continued)

SAMPLE ID	SAMPLING LOCATION	SAMPLING DATE	SAMPLING TIME	THC (ppm)	CO2 (ppm)	CHAMBER GAS TEMP DEG C	CHAMBER SOIL TEMP DEG C	GAS CANISTER ID	OUTSIDE AIR TEMP DEG C	OUTSIDE SOIL DEG C	EPA OUT SOIL DEG C	% CHAMBER SURFACE SHADED
C293	C14	10-25-84	615	26	290	9	10	C294	10	10	10	100
C298	C15	10-25-84	655	31	184	10	10		10	9	10	100
C299	C07	10-25-84	731	57	260	10	11	C301	11	10	9	100
C308	C19	10-25-84	843	19	331	21	15	C311	19	19	20	
C316	C15	10-25-84	1257	90	457	42	34	C317	36	32	35	
C320	C11	10-25-84	1330	70	274	40	50		36	38	41	
C324	C01	10-25-84	1403	69	348	42	32		36	36	39	
C326	C13	10-26-84	900	20	179							100
C333	C11	10-26-84	1005	16	124							70
C336	C01	10-26-84	1036	21	141			C337				
C341	C15	10-26-84	1107	2	86			C342				50
➤C347	C11	10-26-84	1306	34	312			C348				
C350	C10	10-26-84	1337	71	353							
C356	C15	10-26-84	1408	93	312							
C359	C17	10-26-84	1435	5	287			C360				50
C371	C20	11-8-84	1042	2	114	33	26	C372	25	25	28	65
C374	C15	11-8-84	1120	2	221	36	28		30	27	31	50
C377	C08	11-8-84	1157	2	124	39	32		25	28	28	50
C384	C11	11-8-84	1307	1	135	32	34		26	29	31	15
C391	C06	11-8-84	1350	1	57	33	35	C392	26	29	26	60
C395	C15	11-8-84	1427	0	96	31	32	C396	25	34	35	50
C398	C11	11-8-84	1502	4	102	27	23		22	23	22	80
C400	C14	11-8-84	1536	1	219	27	22		23	21	22	100
C408	C11	11-9-84	929	0	126	30	24	C409	22	19	19	80
C413	C13	11-9-84	1001	0	74	34	29		24	25	24	70
C415	C14	11-9-84	1033	0	170	34	37		25	30	36	50
C419	C15	11-9-84	1108	0	146	34	23		28	30	35	40
➤C423	C15	11-9-84	1313	1	27	31	27	C424	25	22	24	
C426	C11	11-9-84	1346	12	271	28	25		24	24	26	20
C430	C04	11-9-84	1417	8	130	30	30		25	26	27	50
C434	C06	11-9-84	1451	5	232	29	25	C435	25	26	21	90
C445	C05	11-10-84	946	1	171	32	30		25	19	20	75
C448	C11	11-10-84	1033	0	116	37	25	C449	33	21	20	50
C452	C21	11-10-84	1120			42	34	C453	37	30	30	50
C460	C15	11-10-84	1259	39	386	40	32		27	31	32	50
C465	C07	11-10-84	1346	38	486	39	28	C463	24	28	26	50
C470	C11	11-10-84	1435	25	412	36	35	C471	24	26	26	90
C475	C11	11-12-84	821	8	137	26	17		18	16	18	100
C479	C15	11-12-84	850	8	218	28	19		20	18	22	100
C485	C21	11-12-84	952	19	260	33	23		24	24	23	80
C489	C01	11-12-84	1026	17	199	28	27	C490	20	23	25	100
➤C494	C05	11-12-84	1133	46	123	28	23	C496	22	22	22	100
C502	C13	11-12-84	1236	43	298	28	25		23	25	25	60
C510	C11	11-12-84	1305	47	330	31	24		23	23	23	10
C511	C15	11-12-84	1338	51	309	36	32	C507+8	27	24	24	40

TABLE 5. RESULTS OF OFF-SITE GC ANALYSES OF FLUX CHAMBER GAS SAMPLES

FIELD SAMPLE ID	SAMPLING LOCATION	SAMPLING DATE	SAMPLING TIME	PARAFFIN ug/m3	OLEFINS ug/m3	TOTAL AROMATICS ug/m3	TOTAL HALO-HC ug/m3	TOTAL OXYG-HC[a] ug/m3	UNIDENTIF VOC ug/m3	TOTAL NMHC ug/m3
C021	A07	10-9-84	1810	1047	131	336	241	1250	6	1761
C040	A19	10-10-84	1110	240100	41420	137900	59	2475	256	419700
C046	A20	10-10-84	1145	223200	29750	81070	386	2197	0	334400
C049	A07	10-10-84	1235	172100	26360	92510	346	1567	0	291300
C056	A03	10-10-84	1330	338600	56110	214000	85	4738	518	609300
C070	A07	10-10-84	1545	277200	46870	101400	108	892	594	426100
C071	A07	10-10-84	1545	238500	38230	93840	85	2960	356	371000
C075	A19	10-10-84	1632	107900	17780	49110	1159	539	862	176800
C083	A14	10-10-84	1752	67290	10270	19440	63	262	202	97270
C085	A17	10-11-84	600	25210	1321	6286	0	0	0	32820
C092	A13	10-11-84	644	13460	2705	5754	81	91	7	22010
C096	A07	10-11-84	728	47980	9001	14690	61	172	118	71850
C100	A19	10-11-84	812	15110	1397	5195	156	246	269	22130
C100B	A19	10-11-84	812	16850	1973	5440	15	484	16	24300
C100D	A19	10-11-84	814	19800	1858	7379	35	288	39	29110
C100DB	A19	10-11-84	814	14590	1550	4907	35	460	0	21080
C104	A07	10-11-84	918	50290	7135	14940	46	142	175	72580
C113	A19	10-11-84	1010	36310	4195	14960	0	1601	0	55470
C136	A19	10-12-84	952	26110	2624	10490	217	0	0	39440
C141	A07	10-12-84	1100	124400	27450	51300	264	466	275	203700
C153	A07	10-12-84	1315	148400	47240	88460	1159	1044	199	285500
C158	A06	10-12-84	1442	168000	34670	93440	111	751	930	297100
C162	A12	10-12-84	1520	75820	17590	34860	179	332	139	128600
C175	A07	10-13-84	913	35010	8640	15320	0	125	71	59040
C176	A07	10-13-84	915	21980	1520	7938	0	0	0	31440
C198	A19	10-13-84	1425	36590	9279	17490	327	149	72	63750
C224	A19	10-23-84	1105	3306	626	2980	16	157	5	6932
C234	A21	10-23-84	1240	25380	8857	12830	0	445	0	47070
C245	A19	10-23-84	1518	2877	363	1506	266	11	239	5252
C255	A07	10-24-84	851	4594	824	1664	281	16	3	7366
C261	A19	10-24-84	1002	2413	669	1240	364	58	9	4694
C272	A19	10-24-84	1310	11060	3865	8759	279	47	337	24300
C272B	A19	10-24-84	1310	10950	2661	8931	295	68	254	23090
C280	A12	10-24-84	1500	19570	4016	17300	6	89	355	41250
C284	A15	10-24-84	1535	50400	14270	20500	123	168	87	85370
C292	A07	10-25-84	615	8956	1405	4231	27	38	87	14710
C297	A17	10-25-84	656	5185	1113	2123	20	17	6	8447
C310	A05	10-25-84	847	6612	1247	6058	63	36	331	14310
C319	A08	10-25-84	1302	16080	2999	12660	365	63	553	32660
C331	A07	10-26-84	1003	17530	5181	11340	39	74	0	34090
C346	A07	10-26-84	1305	131200	29580	108900	0	1174	6156	275800
C346B	A07	10-26-84	1305	122900	20640	100100	0	744	2946	246500
C352	A19	10-26-84	1338	13540	2043	7532	3	117	143	23260
C353	A19	10-26-84	1340	10820	2888	5934	223	47	84	19950
C354	A16	10-26-84	1411	18470	7144	9859	6	83	14	35490
C369	A03	11-8-84	938	1791	180	1854	72	191	91	3988
C383	A07	11-8-84	1250	6336	1756	7957	223	489	464	16740
C389	A12	11-8-84	1343	2563	356	2220	169	363	139	5448
C390	A12	11-8-84	1345	2646	508	2974	166	265	8	6302
C418	A19	11-9-84	1103	983	186	511	212	198	38	1929
C428	A07	11-9-84	1405	13850	3426	15470	163	70	723	33630
C432	A19	11-9-84	1431	2410	602	1727	110	253	21	4870

TABLE 5. (Continued)

FIELD SAMPLE ID	SAMPLING LOCATION	SAMPLING DATE	SAMPLING TIME	PARAFFIN ug/m3	OLEFINS ug/m3	TOTAL AROMATICS ug/m3	TOTAL HALO-HC ug/m3	TOTAL OXYG-HC[a] ug/m3	UNIDENTIF VOC ug/m3	TOTAL NMHC ug/m3
C443	A11	11-10-84	942	2493	723	3031	226	150	4	6477
C462	A05	11-10-84	1335	4727	1048	5823	441	405	138	12180
C467	A07	11-10-84	1433	10780	2180	10320	193	689	634	24100
C468	A07	11-10-84	1436	8594	1472	7439	134	740	1000	18640
C468B	A07	11-10-84	1436	8684	1826	7582	135	694	963	19190
C478	A08	11-12-84	837	2268	813	1389	66	284	61	4597
C488	A19	11-12-84	1011	667	71	330	45	178	0	1113
C493	A07	11-12-84	1129	16310	2526	12050	64	1137	3811	34760
C498	A19	11-12-84	1203	2469	325	1533	54	328	43	4424
C015	B11	10-9-84	1710	493	100	257	353	427	9	1211
C018	B04	10-9-84	1808	454	207	237	97	435	4	1000
C164	B15	10-12-84	1536	2966	310	1674	113	0	0	5062
C189	B13	10-13-84	1152	1903	426	1690	188	73	64	4271
C225	B01	10-23-84	1147	2037	659	1093	358	74	0	4198
C278	B13	10-24-84	1413	10840	3913	7042	281	364	0	22080
C329	B14	10-26-84	933	1238	263	537	26	79	0	2065
C329B	B14	10-26-84	933	1340	272	629	35	121	0	2276
C381	B19	11-8-84	1234	1754	414	1776	35	238	62	4040
C437	B14	11-9-84	1509	841	247	670	138	161	3	1900
C457	B14	11-10-84	1211	1834	547	914	315	296	8	3618
C500	B13	11-12-84	1209	3178	694	3236	50	288	238	7395
C012	C04	10-9-84	1715	1066	131	407	411	502	0	2015
C038	C11	10-10-84	1107	126100	18290	94760	0	490	440	239600
C044	C15	10-10-84	1150	161900	21610	64640	368	1565	0	248500
C044D	C15	10-10-84	1150	227600	31600	105700	58	1156	752	365700
C051	C10	10-10-84	1258	301800	71080	163600	117	2212	443	537000
C063	C19	10-10-84	1435	42090	4596	16880	241	920	1289	65100
C067	C09	10-10-84	1528	117800	16660	45110	100	1578	123	179800
C074	C11	10-10-84	1617	70290	8992	28860	353	487	0	108500
C080	C15	10-10-84	1734	21500	4898	9089	178	534	27	35690
C087	C11	10-11-84	605	13550	2890	8317	56	50	62	24880
C090	C15	10-11-84	646	931	84	289	6	87	0	1311
C095	C07	10-11-84	727	16510	2869	6739	0	150	37	26160
C103	C09	10-11-84	850	25090	5793	9217	5	95	108	40210
C111	C15	10-11-84	1008	1090	223	584	57	0	0	1954
C117	C11	10-11-84	1047	20210	5315	12430	243	86	77	38270
C117B	C11	10-11-84	1047	17800	5248	11660	244	85	90	35040
C118	C11	10-11-84	1051	16420	4072	10820	108	72	39	31460
C123	C17	10-11-84	1138	57060	9817	21020	6	211	220	88120
C134	C01	10-12-84	950	126800	18160	59280	87	513	0	204300
C148	C03	10-12-84	1218	321100	75960	176100	358	1639	325	573800
C154	C15	10-12-84	1324	534200	102800	229500	53	2064	2265	868700
C156	C11	10-12-84	1400	409800	70170	141000	76	1494	1109	622100
C156B	C11	10-12-84	1400	382400	69680	148400	60	1404	653	601200
C169	C13	10-12-84	1618	163600	26930	55530	0	648	0	246000
C182	C15	10-13-84	1032	155500	21770	63060	137	1407	105	240600
C195	C13	10-13-84	1354	59160	15260	31750	0	204	121	106300
C195B	C13	10-13-84	1354	66500	18270	34540	17	260	156	119500
C207	C15	10-13-84	1538	94540	11290	31370	0	380	0	137200
C216	C11	10-23-84	948	18200	5140	7785	44	70	38	31210

TABLE 5. (Continued)

FIELD SAMPLE ID	SAMPLING LOCATION	SAMPLING DATE	SAMPLING TIME	PARAFFIN ug/m3	OLEFINS ug/m3	TOTAL AROMATICS ug/m3	TOTAL HALO-HC ug/m3	TOTAL OXYG-HC[a] ug/m3	UNIDENTIF VOC ug/m3	TOTAL NMHC ug/m3
C229	C05	10-23-84	1149	8230	2574	7240	781	85	38	18860
C231	C02	10-23-84	1228	6926	2610	4642	543	88	48	14770
C250	C15	10-23-84	1555	5738	875	3621	2	26	58	10290
C263	C11	10-24-84	1006	14480	4456	7156	41	49	12	26150
C264	C11	10-24-84	1010	12350	3636	7218	217	59	19	23440
C286	C11	10-24-84	1535	89680	17340	31900	0	433	217	139100
C294	C14	10-25-84	620	8251	1783	3493	55	37	8	13590
C301	C07	10-25-84	733	20990	4019	4921	83	62	45	30060
C311	C19	10-25-84	845	6175	1473	2778	154	54	0	10580
C317	C15	10-25-84	1258	31210	8521	18040	0	135	24	57790
C337	C01	10-26-84	1040	11470	2849	6580	36	124	102	21040
C337B	C01	10-26-84	1040	11740	2062	8117	32	143	0	21950
C342	C15	10-26-84	1109	10580	2668	6179	19	103	0	19440
C348	C11	10-26-84	1310	69600	17490	28430	3	279	123	115600
C360	C17	10-26-84	1437	38700	10770	19990	1	129	67	69540
C372	C20	11-8-84	1048	2292	527	1719	23	165	14	4575
C392	C06	11-8-84	1352	1989	224	1586	13	8	174	4272
C396	C15	11-8-84	1430	6393	2000	5283	20	622	10	13710
C396B	C15	11-8-84	1430	6507	1236	4192	21	477	0	11960
C409	C11	11-9-84	931	2922	676	2467	45	216	42	6152
C424	C15	11-9-84	1316	16850	4973	14890	51	63	1042	37810
C435	C06	11-9-84	1453	5687	774	5847	38	465	245	12590
C449	C11	11-10-84	1035	14510	3493	14510	230	928	286	33040
C453	C21	11-10-84	1123	11780	4637	10180	80	571	26	26710
C463	C07	11-10-84	1348	9490	2121	7224	49	42	237	19120
C471	C11	11-10-84	1437	8311	1331	7236	120	590	137	17130
C490	C01	11-12-84	1028	2258	492	1542	81	224	0	4373
C496	C05	11-12-84	1137	9008	3062	10170	80	40	460	22780
C507	C15	11-12-84	1342	14890	5437	9352	49	1012	0	29730
C508	C15	11-12-84	1344	16460	6982	11480	57	70	42	35020

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[a] The recovery of oxygenated hydrocarbon species from the GC system used is variable. In this and subsequent tables, the total oxygenated-hydrocarbon values are included for completeness. They are not included in the total NMHC values.

TABLE 6. RESULTS OF OFF-SITE GC ANALYSES OF AMBIENT AIR SAMPLES

Field Sample ID	Sampling Location	Sampling Date	Sampling Time	Paraffin (ug/m^3)	Olefins (ug/m^3)	Total Aromatics (ug/m^3)	Total Halo-HC (ug/m^3)	Total Oxyg-HC (ug/m^3)	Uniden. VOC (ug/m^3)	Total NMHC (ug/m^3)
C108	-	10-11-84	24 hr	572	57	63	4	133	0	697
C108B	-	10-11-84	24 hr	581	67	58	6	113	0	712
C139	-	10-12-84	24 hr	820	83	394	19	4	2	1317

LIQUID SAMPLES

Liquid samples were collected of the waste applied initially and of the process water used subsequently to irrigate the landfarm plots.

Sludge Samples

The analytical results of the GC analyses of the sludge samples are summarized in Table 7. Detailed data summary sheets are included in Appendix K. The purgeable organics (i.e., volatile organics) in the sludge averaged 7820 [RSD (relative standard deviation) = 58%] ug/g total NMHC. This represents 0.782% of the applied sludge and 3.96% of the applied oil. The large variability in the measured compositions was not expected. An examination of the results shows that the results are similar for the analyses performed on 10/29/84 and 7/9/85. The results of the 1/8/85 analyses are substantially higher, however. These latter analyses were examined in an attempt to identify possible problems which may have cast some uncertainty on the reported high levels of volatile compounds. No problems were evident.

It is quite possible that the high values were obtained as a result of analyzing a nonrepresentative aliquot of the sludge samples contained in the sample containers. If the contents were not adequately mixed, for example, before withdrawing aliquots, an organic phase may have been analyzed rather than a mixture of organic and water phases. Such an analysis would indeed have produced relatively high levels of volatile organic compounds.

The sludge samples were also analyzed for the oil, water, and solids content. These analyses were performed using the "THF" method developed by Chevron (see Appendix O for details of this procedure). The results are given in Table 8. Results of quality control checks for these tests are given in Section 10. The density of the sludge was determined gravimetrically and found to be 1.07 (RSD = 0.9%). Chevron obtained similar results using their MODT analysis, as indicated in Appendix A.

Service Water

The results of the GC analysis of the refinery service water are summarized in Table 9. The data summary sheet is given in Appendix M. No samples of the irrigation water used were obtained directly. Plant service water was used for irrigation and one sample of this water was collected and analyzed. The volatile organic content of the service water was not expected to change significantly over the five-week test period. The contribution of the irrigation water to the organic content of the landfarm soil was not significant. Assuming a conservative estimate of one Ag-gator load of water per plot per irrigation episode, 0.032 kg of volatile organics were applied per plot over the five-week test period. This is less than 0.05% of the 110 kg of applied volatile organics per plot.

TABLE 7. RESULTS OF OFF-SITE GC ANALYSES OF SLUDGE SAMPLES[c]

Field Sample ID	Sampling Date	Sampling Time	Analysis Type	Analysis Date	Paraffin (ug/g)	Olefins (ug/g)	Total Aromatics (ug/g)	Total Halo-HC (ug/g)	Total Oxyg-HC (ug/g)	Uniden. VOC (ug/g)	Total NMHC (ug/g)
C032[a]	10-10-84	940	Sludge	10-29-84	2165	656	3088	13	128	55	5976
C032[a]	10-10-84	940	Sludge	1-8-85	9188	2373	4839	15	455	188	16600
C032[a,b]	10-10-84	940	Sludge	7-9-85	1360	535	2200	1	102	50	4150
C032[b]	10-10-84	940	Sludge	7-9-85	2020	846	2520	4	5	0	5390
C047[a]	10-10-84	1145	Sludge	10-29-84	1991	1782	1826	13	83	0	5612
C047[a]	10-10-84	1145	Sludge	1-8-85	6844	1544	3256	39	101	0	11680
C047[a]	10-10-84	1145	Sludge	7-9-85	1880	713	2730	2	162	37	5360

[a] Duplicate sample.

[b] Duplicate analysis.

[c] Sample C032 taken from first tanker load; Sample C047 taken from second tanker load.

TABLE 8. RESULTS OF SLUDGE ANALYSIS BY CHEVRON METHOD

Field Sample	Wt. % Solids	Wt. % Water	Wt. % Oil
C032	8.60 (RSD = 2.44%)	71.6 (RSD = 3.1%)	19.8 (RSD = 11%)

TABLE 9. RESULTS OF OFF-SITE GC ANALYSES OF SERVICE WATER SAMPLE

Field Sample ID	Sampling Date	Sampling Time	Paraffin (mg/1)	Olefins (mg/1)	Total Aromatics (mg/1)	Total Halo-HC (mg/1)	Total Oxyg-HC (mg/1)	Uniden. VOC (mg/1)	Total NMHC (mg/1)
C474	11-12-84	810	0.063	0.006	0.000	0.004	0.000	0.016	0.089

SOIL SAMPLES

Soil cores were collected for determination of physical properties of the soil. Grab soil samples were collected for percent moisture, oil and grease, and microbe count determinations.

Soil Cores

The results of the physical properties determinations for the soil core samples are given in Tables 10 and 11.

Grab Soil Samples

The samples collected and their respective analytical results are given in Table 12 and summarized in Table 13. Analytical results obtained by Chevron Corporation personnel from samples they independently collected are given in Appendix A and the analytical method used by Chevron is given in Appendix P.

TABLE 10. RESULTS OF PHYSICAL AND CHEMICAL TESTING ON CORE SAMPLES

Field Sample ID	Sampling Location	Sampling Date	Sampling Time	Particle Density (g/cm^3)	Wt. % Moisture (dry basis)	Bulk Density (g/cm^3)	% Porosity	Oil and Grease (mg/g)
C033	C11	10-10-84	1045	2.53	9.16	1.29	49.0	63
C034	A19	10-10-84	1050	2.29	5.73	1.01	56.0	87
C109	A19	10-11-84	0946	2.30	6.70	0.80	65.1	70
C116	C11	10-11-84	1034	2.64	8.19	1.43	45.8	21
C149	C15	10-12-84	1308	2.57	5.84	1.40	45.4	50
C163	A12	10-12-84	1511	2.65	10.53	1.30	51.0	70
C197	A19	10-13-84	1415	2.44	6.07	1.09	55.3	51
C206	C15	10-13-84	1525	2.54	6.99	1.35	46.9	99
C221	A19	10-23-84	1047	2.53	7.34	1.39	45.1	14
C246	C19	10-23-84	1509	2.55	8.44	1.45	43.3	98

TABLE 11. PARTICLE SIZE DISTRIBUTION FOR CORE SAMPLES

Particle Diameter (um)	Field Sample ID (cumulative percent less than)									
	C033	C034	C109	C116	C149	C163	C197	C206	C221	C246
2000	94.6	95.3	98.7	99.1	98.6	100	95.7	—	89.3	100
710	84.3	91.1	95.0	91.6	87.2	98.9	81.0	—	78.7	97.4
595	—	82.3	91.7	82.3	80.9	97.5	71.6	96.7	69.1	88.5
425	58.2	61.9	80.8	63.4	64.5	89.6	53.8	—	46.3	66.8
250	—	23.0	42.5	21.5	25.9	42.2	19.1	33.4	14.5	19.0
212	21.5	—	35.4	—	20.0	—	15.6	—	—	—
150	17.3	15.3	28.3	13.6	14.6	25.3	11.8	—	7.63	9.36
125	—	13.4	26.5	11.1	13.6	21.5	10.5	14.0	6.66	8.06
75	14.3	10.1	22.7	6.66	12.6	17.2	7.80	13.4	5.39	6.23
53–59	0.2	2.7	4.7	12.2	2.2	12.4	2.3	2.3	1.4	4.5
38–42	0.2	2.7	3.7	10.2	2.2	11.4	2.3	2.3	1.4	3.5
31–34	0.2	1.5	3.7	10.2	2.2	11.4	2.3	2.3	1.4	3.5
27–29	0.2	1.5	2.6	8.2	2.2	10.4	2.3	2.3	0.4	3.5
19–21	0.2	1.5	2.6	6.2	2.2	9.4	1.3	2.3	0.4	1.4
14–15	0	1.5	2.6	4.2	1.2	8.4	0.2	2.3	0.4	1.4
10–11	0	1.5	2.6	4.2	0.2	8.4	0.2	2.3	0.4	1.4
7–8	0	0.4	1.5	3.2	0.2	6.4	0.2	0.2	0.4	0.4
5–6	0	0.4	1.5	2.2	0.2	4.4	0	0.2	0.4	0.4
4	0	—	—	0.2	0.2	4.4	0	0.2	0.4	0

TABLE 12. RESULTS OF ANALYSES OF SOIL GRAB SAMPLES

Field Sample ID	Sampling Location	Sampling Date	Sampling Time	Percent Moisture	Oil and Grease mg/g	Microbe Count bug/g 10x5
C022	A07	10-9-84	1805			
C026	A07	10-10-84	730			
C027	A19	10-10-84	735	11.0	51	
C036	A19	10-10-84	1110	12.0	85	3
C042	A20	10-10-84	1140	11.0	86	
C052	A07	10-10-84	1240	12.0	44	
	A07	10-10-84	1240			
C059	A03	10-10-84	1400			
C066	A12	10-10-84	1400			
	A07	10-10-84	1533			
	A19	10-10-84	1617			
	A19	10-10-84	1617			
	A14	10-10-84	1723			
	A17	10-11-84	534			
C088	A13	10-11-84	625			
	A07	10-11-84	719			
	A19	10-11-84	806			
	A07	10-11-84	915			
	A07	10-11-84	915			
C114	A19	10-11-84	1004	22.0	16	6
	A14	10-11-84	1119			
C124	A16	10-11-84	1136	9.4	60	2
C132	A19	10-12-84	921	11.0	51	52
C140	A07	10-12-84	1053	9.0	45	3
	A07	10-12-84	1308			
	A19	10-12-84	1402			
	A06	10-12-84	1424			
	A06	10-12-84	1424			
C160	A12	10-12-84	1458	10.0	52	45
C183	A13	10-13-84	1043	11.0	52	6
C191	A07	10-13-84	1335			
C196	A19	10-13-84	1410	9.6	35	15
C217	A11	10-23-84	1007	9.5	77	21
C220	A19	10-23-84	1038			
C243	A19	10-23-84	1500	9.3	86	30
C253	A07	10-24-84	845	8.5	51	9
C259	A19	10-24-84	950			
C268	A15	10-24-84	1104	8.5	74	78

TABLE 12. (Continued)

Field Sample ID	Sampling Location	Sampling Date	Sampling Time	Percent Moisture	Oil and Grease mg/g	Microbe Count bug/g 10x5
C304	A15	10-25-84	800	9.7	58	59
C307	A05	10-25-84	824			
C322	A07	10-25-84	1340	10.0	50	48
C335	A19	10-26-84	1020			
C339	A08	10-26-84	1048	9.9	46	19
C349	A19	10-26-84	1319	11.0	64	19
	A05	11-7-84	12-1500			
	A10	11-7-84	12-1500			
	A12	11-7-84	12-1500			
	A17	11-7-84	12-1500			
	A19	11-7-84	12-1500			
	A19	11-7-84	12-1500			
	A21	11-7-84	12-1500			
C367	A03	11-8-84	931			
C375	A19	11-8-84	1120	9.4	73	21
	A07	11-8-84	1208			
	A07	11-8-84	1229			
C387	A12	11-8-84	1327	10.0	66	28
	A19	11-8-84	1415			
	A19	11-8-84	1415			
C405	A07	11-9-84	855	9.4	46	10
C416	A19	11-9-84	1045	12.0	69	
C422	A20	11-9-84	1307			
	A07	11-9-84	1401			
	A19	11-9-84	1418			
C446	A07	11-10-84	1006	12.0	39	34
C454	A18	11-10-84	1142			
C461	A05	11-10-84	1310	10.0	35	25
C480	A07	11-12-84	851	12.0	43	9
C486	A19	11-12-84	954	13.0	68	20
C503	A21	11-12-84	1224			
C016	B11	10-9-84	1710			
C019	B04	10-9-84	1810			
	B06	10-10-84	1343			
	B17	10-10-84	1415			
	B15	10-10-84	1653			
	B11	10-10-84	1709			

TABLE 12. (Continued)

Field Sample ID	Sampling Location	Sampling Date	Sampling Time	Percent Moisture	Oil and Grease mg/g	Microbe Count bug/g 10x5
	B06	10-11-84	800			
	B17	10-11-84	838			
C119	B15	10-11-84	1046	8.6	32	
	B11	10-11-84	1220			
C166	B15	10-12-84	1534	9.9	49	4
	B18	10-12-84	1617			
C188	B13	10-13-84	1129	9.5	52	
C226	B01	10-23-84	1150	7.7	43	7
C276	B13	10-24-84	1351	9.6	41	26
C302	B03	10-25-84	751	8.2	47	5
C358	B06	10-26-84	1425	9.4	49	21
	B01	11-7-84	12-1500			
	B03	11-7-84	12-1500			
	B08	11-7-84	12-1500			
	B13	11-7-84	12-1500			
	B15	11-7-84	12-1500			
	B20	11-7-84	12-1500			
C379	B19	11-8-84	1224	11.0	46	53
C410	B03	11-9-84	932	11.0	55	5
C458	B04	11-10-84	1230	9.7	46	1
C505	B21	11-12-84	1255	9.9	61	9
C013	C04	10-9-84	1715			
C028	C15	10-10-84	740			
C029	C11	10-10-84	745	8.5	60	
C035	C11	10-10-84	1055			
C041	C15	10-10-84	1130			
C053	C10	10-10-84	1250	11.0	47	21
C054	C15	10-10-84	1230			
C061	C19	10-10-84	1417			
C068	C09	10-10-84	1520			
	C11	10-10-84	1608			
	C15	10-10-84	1720			
	C10	10-10-84	1810			
C093	C11	10-11-84	640	9.9	34	
	C15	10-11-84	627			
	C15	10-11-84	627			

TABLE 12. (Continued)

Field Sample ID	Sampling Location	Sampling Date	Sampling Time	Percent Moisture	Oil and Grease mg/g	Microbe Count bug/g 10x5
	C07	10-11-84	715			
	C09	10-11-84	828			
	C06	10-11-84	916			
C107	C15	10-11-84	945	12.0	54	
C115	C11	10-11-84	1034			
	C17	10-11-84	1122			
C144	C15	10-12-84	1136	11.0	38	
	C15	10-12-84	1312			
C155	C11	10-12-84	1345	8.7	22	4
	C05	10-12-84	1425			
C193	C13	10-13-84	1338	13.0	44	61
C200	C02	10-13-84	1417	12.0	63	
C202	C11	10-13-84	1443	10.0	53	10
C205	C15	10-13-84	1514			
C214	C11	10-23-84	931	9.1	104	10
C230	C02	10-23-84	1210	9.0	390	3
C242	C19	10-23-84	1455			
C265	C19	10-24-84	1025	9.6	61	12
C273	C01	10-24-84	1318			
C279	C13	10-24-84	1437	8.6	1	51
C290	C14	10-25-84	602			
C295	C15	10-25-84	640	10.0	48	38
C306	C19	10-25-84	816	9.5	65	65
C325	C13	10-26-84	850	7.6	98	29
C334	C01	10-26-84	1025			
C355	C15	10-26-84	1355	9.3	32	16
	C05	11-7-84	12-1500			
	C10	11-7-84	12-1500			
	C12	11-7-84	12-1500			
	C17	11-7-84	12-1500			
	C17	11-7-84	12-1500			
	C19	11-7-84	12-1500			
	C19	11-7-84	12-1500			
	C21	11-7-84	12-1500			
	C21	11-7-84	12-1500			
	C15	11-8-84	1112			
	C15	11-8-84	1112			
C386	C11	11-8-84	1252	12.0	62	108

TABLE 12. (Continued)

Field Sample ID	Sampling Location	Sampling Date	Sampling Time	Percent Moisture	Oil and Grease mg/g	Microbe Count bug/g 10x5
C394	C15	11-8-84	1415	9.3	54	50
C399	C14	11-8-84	1518			
	C11	11-8-84	1501			
C407	C11	11-9-84	915	11.0	40	27
	C15	11-9-84	1105			
	C15	11-9-84	1105			
	C11	11-9-84	1331			
C429	C04	11-9-84	1409			
C433	C06	11-9-84	1442	9.4	44	24
C444	C05	11-10-84	930	12.0	50	18
C450	C21	11-10-84	1051			
C469	C11	11-10-84	1407	14.0	53	66
C476	C15	11-12-84	837	9.7	79	
C484	C21	11-12-84	940			
C501	C13	11-12-84	1221	10.0	56	120

TABLE 13. SUMMARY OF ANALYTICAL RESULTS FOR SOIL GRAB SAMPLES

		Radian					
		Moisture Content		Oil Content (Wet)		Oil Content (Dry)	
Plot	Sampling Period	Weight Percent	RSD (%)	mg/g	RSD (%)	mg/g	RSD (%)
A	10/10-10/13	11.7	31	49	51	59.2	37.5
	10/23-10/26	9.6	8.3	63	22	69.9	21.3
	11/7-11/12	11.0	12	55	27	61.7	26.6
B	10/10-10/13	9.3	5.4	44	20	49.0	20.4
	10/23-10/26	8.7	9.2	45	7.1		
	11/7-11/12	10.4	5.8	52	12	58.0	12.1
C	10/10-10/13	10.7	13	46	26	51.7	27.1
	10/23-10/26	9.1	7.7	68	38	74.7	37.2
	11/7-11/12	10.9	14	55	20	61.5	20.2

SECTION 7

STATISTICAL ANALYSIS

A statistical analysis was performed primarily to determine the effect of application method and temperature inside the chamber on the measured emission rates of volatile organics. The statistical analysis of the study data consisted of several stages of data evaluation. First, the frequency distribution of the emission rate data was examined. Due to the high degree of skewness in the distribution of emission rate values, a lognormal distribution was used to model the distribution of emission rates. In order to determine whether measurable differences exist among the emission rate levels for the control, surface, and subsurface-applied test plots, an analysis of covariance was performed. The analysis of covariance technique eliminates the variation in emission rate due to time, temperature inside the chamber, and chamber surface shading so that corrected average emission rates for the test plots can be compared directly. Outlier tests were performed on the residuals resulting from the analysis of covariance. Results from the analysis of covariance were also used in developing a correction factor equation which can be used to correct the measured emission rate to temperatures outside the chamber. A more detailed discussion of the statistical techniques used and results of the analyses are presented below.

DEVELOPMENT OF THE DATABASE

Prior to the analysis, the analytical data were entered into a database for manipulation on the SAS system (9). SAS is a computer system designed for data analysis, which provides information storage and retrieval, data modification and programming, statistical analysis, and file handling. Evaluation and interpretation of the test results were performed using SAS General Linear Model routines. The results of a total of 200 air samples were used in this analysis. For the statistical analysis, Varian (off-site canister) results were used only for those days on which Byron (on-site syringe) results were deemed unacceptable due to instrument problems. Temperature measurements inside the chamber were taken for 120 of these samples, and surface shading measurements were made for 74 of the samples.

STATISTICAL DISTRIBUTION MODEL

Many standard statistical methods are strictly applicable only if the data are normally distributed. Thus, before the statistical analysis was begun, the statistical distribution exhibited by the emission rate data was investigated. Examination of a histogram of the emission rate data (see Figure G-1 in Appendix G) indicated a high degree of skewness to the right. The lognormal distribution, which is usually appropriate when the standard error of an individual value is proportional to the magnitude of the value, was used to model the distribution of emission rates. This distribution has the property that when the original data are transformed by taking natural logarithms, the transformed data will follow a normal (Gaussian) distribution. The distribution assumptions were tested by examining the distribution of the log emission rate values. A histogram displaying the distribution was constructed (Figure G-2 in Appendix G). The data appeared to approximate a normal distribution.

To statistically test the assumption of a normal distribution for the log-emission rates, a Kolomogorov-D statistic was computed and tested for significance. This test confirmed the conclusion from the histogram that the log-emission rate data follow a normal distribution. Through use of the logarithmic transformation, statistical methods applicable for the normal distribution can validly be used. The lognormal distribution is one of the most commonly used distribution models for environmental data.

For the statistical analysis development work, it was considered desirable to avoid predicting negative emission rates. Using log-emission rates provides a functional form of a linear equation which always predicts positive emission rate values. Such an equation appeared to be more in accordance with the nature of emissions than an equation which allows negative emission rate predictions. For determining the effect of application method and developing a correction factor equation, an equation of the following form was used:

$$\log\ (ER) = B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4 \tag{7}$$

or

$$\begin{aligned} ER &= \exp(B_0 + B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4) \qquad (8) \\ &= K \exp(B_1X_1 + B_2X_2 + B_3X_3 + B_4X_4) \end{aligned}$$

where ER = emission rate, $K = \exp(B_0)$, the B's are coefficients estimated through the ANCOVA analysis, and the X's are the predictor variables (i.e., time, chamber temperature, test plot, and sampling location within a plot).

While non-negativity is desirable, the functional form must also be adequate to fit the data. It was verified through a series of data plots that the exponential functional form was adequate. Specifically, the difference between observed and predicted emission rate values (residuals) were plotted against the predictor variables after completion of the ANCOVA analysis. These and other plots revealed no unexplained trend in the data; i.e., the plots indicated that the exponential equation fit the data.

ANALYSIS OF COVARIANCE

The analysis of covariance (ANCOVA) technique performed on the log-emission rate data was used:

(1) to determine the effect of application method on VOC emissions, and

(2) to develop a correction factor equation which can be used to adjust the measured emission rate to temperatures outside the flux chamber.

Results from the ANCOVA also provided components of variability estimates associated with the emission rate measurements.

Effect of Application Method

To determine the effect of application method on emissions, the ANCOVA technique was used to test the hypothesis that the type of application (surface spreading, subsurface injection, or no application) significantly influences emission rate levels. After the initial ANCOVA analysis was performed, outlier tests were conducted as described below. None of the emission rate measurements were deleted from the database as outliers. From the ANCOVA analysis, the extent to which emission rate measurements were influenced by time, temperature inside the chamber, sampling location within a plot, and chamber surface shading was estimated.

In order to make a direct comparison of application method, the effect of the environmental and sampling parameters on measured emissions must be considered. If these effects were not taken into consideration, emission rate averages for each of the test plots could be biased in different directions. For example, while emission measurements were taken over the same time period for each plot, the same number of measurements on a given day were not made at each plot. Seventy-five percent of the test plot A measurements were taken during the first two weeks of sampling (October 10-26, 1984) when emissions were at their highest. For test plot C and the background plot (test plot B), seventy percent of the measurements were taken during this period. A comparison of the overall emission rate average for each test plot would not be appropriate since emissions would be biased high for test plot A and biased low for test plot C and the background plot.

The ANCOVA essentially minimizes the effects of variation in these environmental and sampling parameters by eliminating their associated variability from the experimental error. If less sophisticated tests (e.g., conventional analysis of variance) had been used, the variance due to these additional factors would have been misinterpreted as additional random variability. This additional random variability would have inflated the error variance, potentially obscuring the effect of application method.

Approach for Development of a Correction Procedure

Results from the ANCOVA discussed above were also used to develop a correction factor equation which can be used to adjust the measured emission rate to temperatures outside the chamber. The approach used to develop a correction procedure involved developing an equation to predict emission rate as a function of time, chamber temperature, test plot, and sampling location within a plot. The functional form of the prediction equation is seen in Equation 8. Inclusion of chamber surface shading in the equation did not improve its predictive capability and substantially reduced the database. The resulting emission rate equation was then used to define a correction factor, C, as follows:

$$C = (ER_s/ER_a) \tag{9}$$

where, ER_s = the predicted value of emission rate at the standard air temperature using the developed equation; and

ER_a = the predicted value of emission rate at the actual air temperature using the developed equation.

The value C is a factor which can be used to correct the measured emission rate to air temperatures outside the chamber:

$$ER_c = C \times ER_m \tag{10}$$

where, ER_c = the corrected value of emission rate; i.e., it is an estimate of the value of the emission rate which would have been observed if the measurement had been performed at outside air temperatures.

ER_m = the measured emission rate.

Outlier Tests

An outlying observation, or outlier, is one that appears to deviate markedly from other members of the sample in which it occurs. Outliers do not fit in with the pattern of the remaining data points and are not at all typical of the rest of the data. If outlying data points are not removed from the data under consideration, they can result in a distortion of the estimate which characterizes the data. Outlying points cannot be removed indiscriminately, however, since they may provide information not available from the other observations.

Outlier testing for individual data points was performed on the residuals from the results of the ANCOVA. Potential outliers were defined as observations that had extremely large residuals from the ANCOVA. Residuals are defined as the difference between an observed or measured concentration and its predicted value. Studentized residuals (raw residuals that are scaled by dividing each by its estimated standard deviation) provide a good measure of the degree to which observations can be considered as outliers. Since the studentized residuals are approximately standard normal variates, observations with residuals that are larger than three in absolute value (corresponding to three standard deviations) were examined closely for possible rejection. Final selection of outliers from those identified as potential outliers included consideration of method precision and expected sampling plus analytical variability.

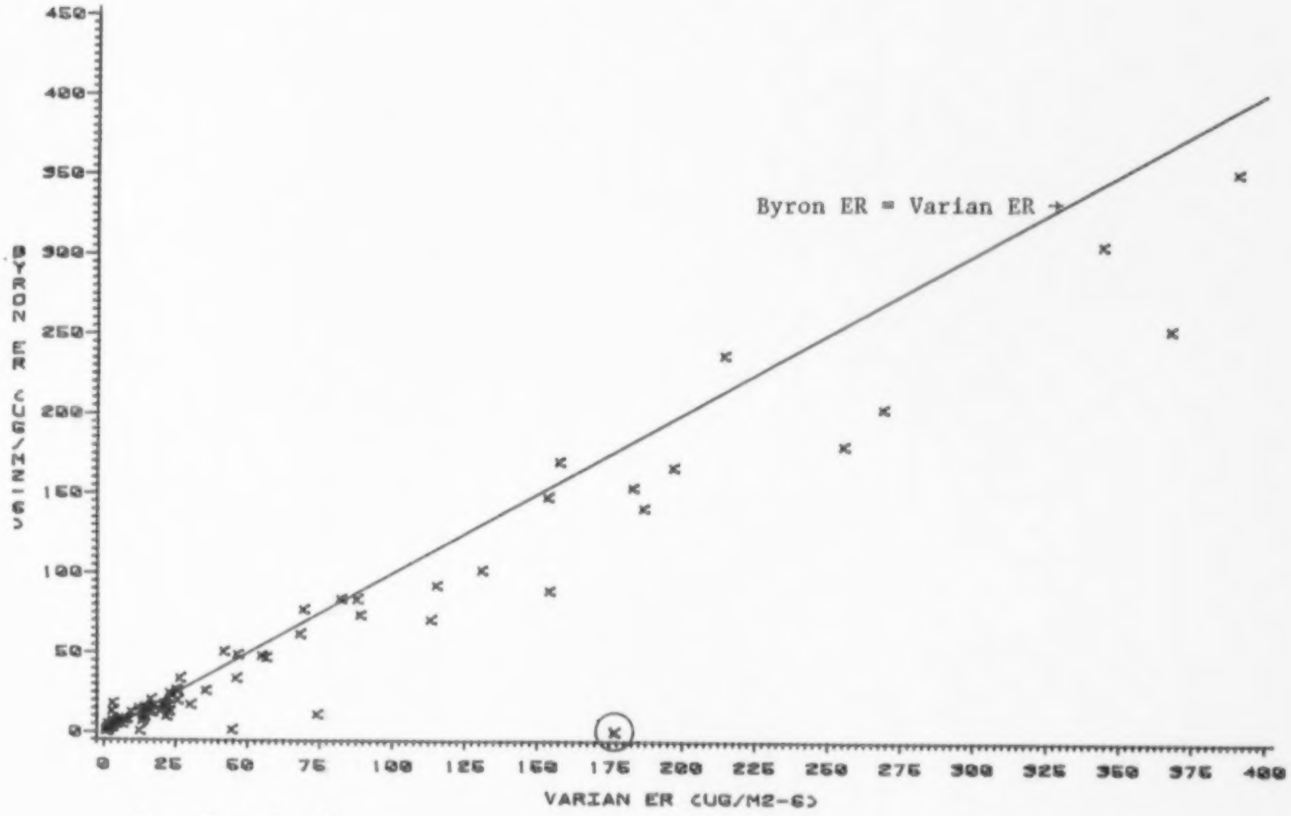
Of a total of 200 emission rate measurements, none were deleted as an outlier. However, 16 measurements made on the first day of sampling (October 9, 1984), before wastes were applied, were not included in the statistical analyses.

STATISTICAL ANALYSIS RESULTS

Emission rates were calculated from both the Byron (on-site/syringe samples) and the Varian (off-site/canister samples) analytical results. The emission rate data for these two methods of analysis were linearly correlated using a regression analysis program. Figure 4 presents a plot of the Byron and Varian emission rate data. One of the Varian samples, sample ID C346, was deleted as an outlier due to its extremely large studentized residual. The corresponding plot character is circled in Figure 4. Although the two methods of analysis are highly correlated, with a linear correlation coefficient of 0.977, the Varian method resulted in significantly higher emission rate values for increased emissions. Differences between the two methods (Byron minus Varian emission rate) ranged from -185 to 139 percent, with an overall average difference of -2.3 percent. Ninety percent of the percent difference values fell between ±75%. The Varian results are consistently higher than the Byron results for periods of high emission rates (>100 ug/m^2-s).

The Byron and Varian data sets were combined for the data interpretation and presentation given in Section 8. The Byron/Varian analytical results can be considered as QC duplicate sample results. Including the Varian results increases the sample size and provides a considerable amount of QC information about the measurement variability at a given time. However, combining the data sets does not provide a significant amount of additional information about the test results. The following discussion of statistical analysis results is based on the Byron data set.

The pair-wise correlation of the various sampling parameters with measured emissions are shown in Table 14. It should be noted that these correlation coefficients measure the strength of the linear relationship between a parameter and measured emissions given that the effects due to the other parameters are not removed. A better indicator of the individual effect these parameters have on emissions is presented below in the ANCOVA discussion. Plots of emission rate versus time, soil temperature (within the flux chamber), air temperature (within the flux chamber), and percent surface shading in the flux chamber are given in Figures 5 through 8, respectively. Differences in the effect of soil and air temperatures (within the flux chamber) on emissions are indistinguishable. The correlation coefficient for the two temperature measurements (r = 0.70) was highly significant. The plot of measured air versus soil temperatures within the flux chamber is shown in Figure 9. ANCOVA analyses were performed to compare the individual effects of soil versus air temperature on measured emissions when the effects due to the other parameters are removed. An ANCOVA analyses was run first using air temperature inside the chamber as the temperature parameter and then using soil temperature inside the chamber. Results from these analyses indicated practically no difference in the



ER = Emission Rate

Figure 4. Correlation of Byron and Varian analytical results.

TABLE 14. PAIR-WISE CORRELATION OF SAMPLING PARAMETERS AND MEASURED EMISSIONS

	Emission Rate		
Parameter[a]	Number of Observations	Correlation Coefficient	Significance Level[b]
Date and Time	149	−0.477	<0.001
Air Temperature[c]	91	0.205	0.05
Soil Temperature[c]	91	0.288	0.006
% Chamber Surface Shaded	57	0.177	0.19

[a] Plots A and C data combined.

[b] The significance level indicates the confidence with which one can conclude that two variables have a true, or repeatable, relationship. If this significance level is 0.001, for example, this means that there is only a probability of 0.001 (one chance in 1,000) that as strong a relationship as the one observed would have occurred if the two variables had no true relationship. Thus, if the significance is low (<0.05), one can conclude with confidence that a true relationship exists.

[c] Inside the flux chamber.

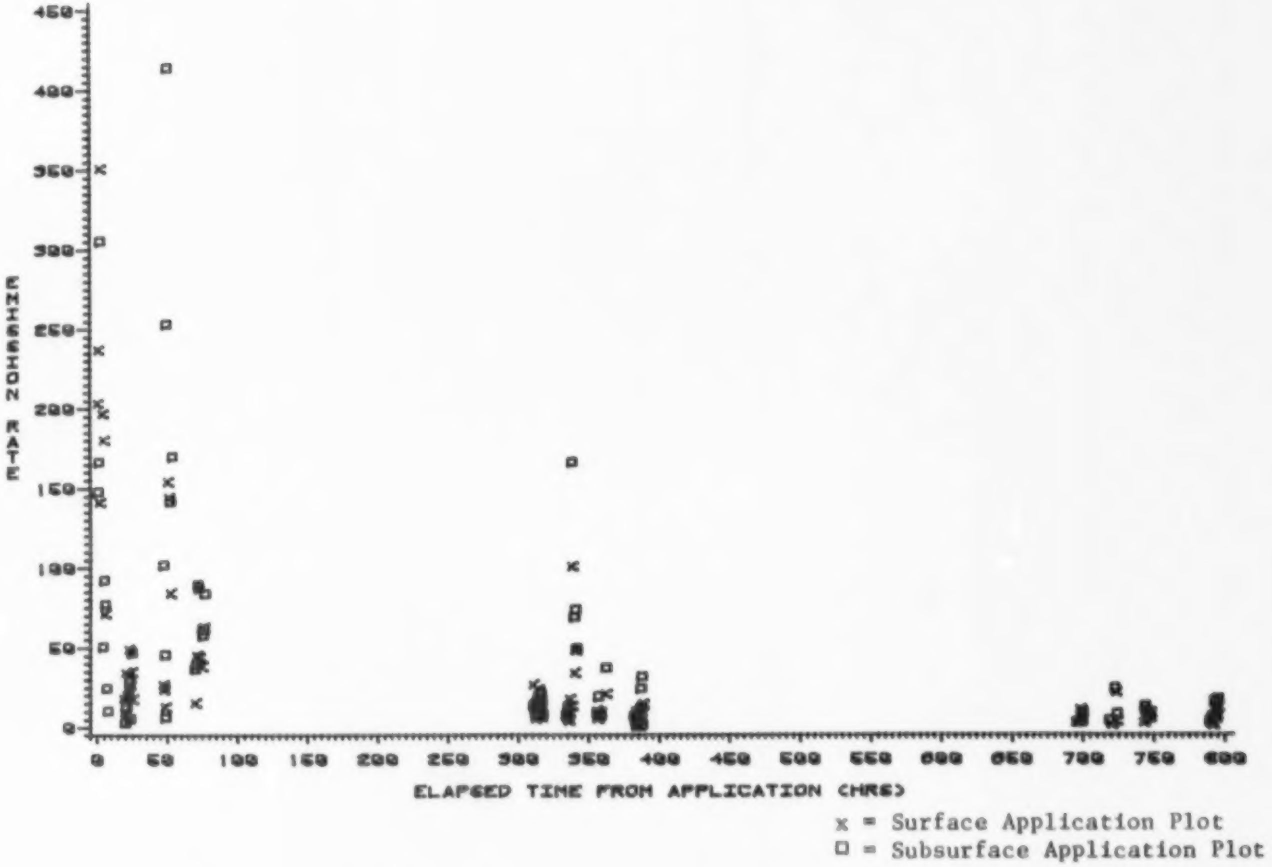


Figure 5. Measured emission rate (ug/m^2-sec) vs. time from application (hours).

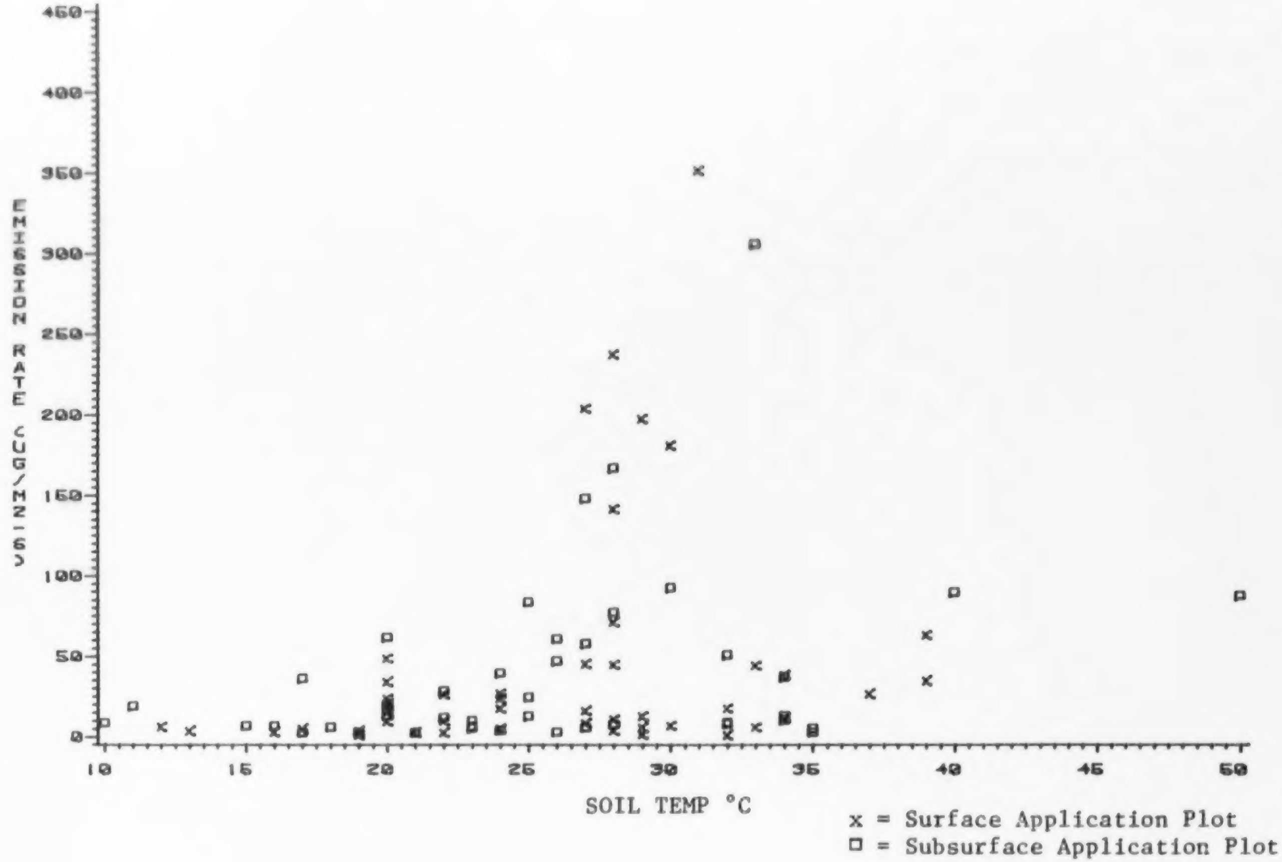


Figure 6. Measured emission rate (ug/m^2-sec) vs. soil temperature inside the chamber.

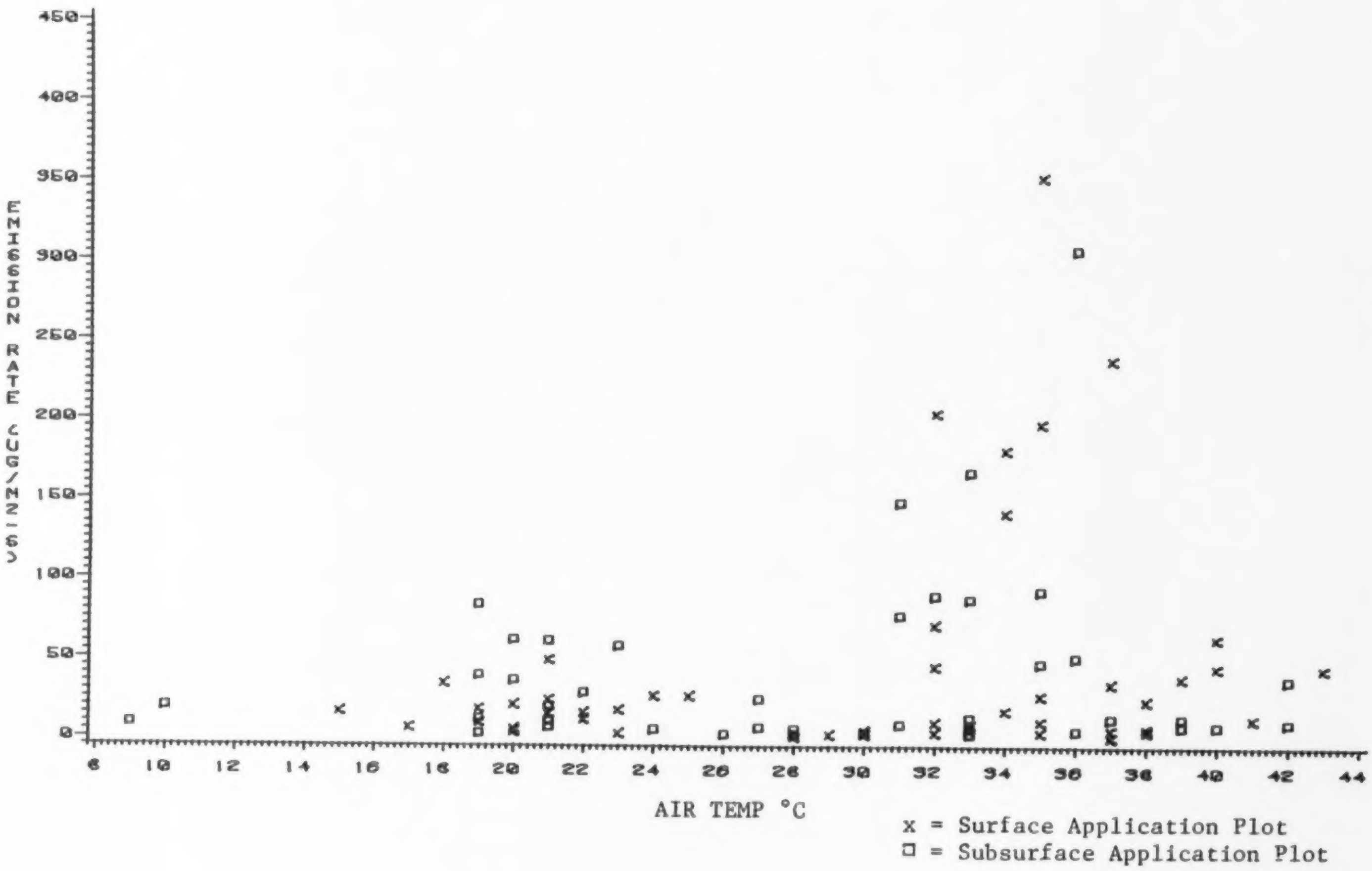
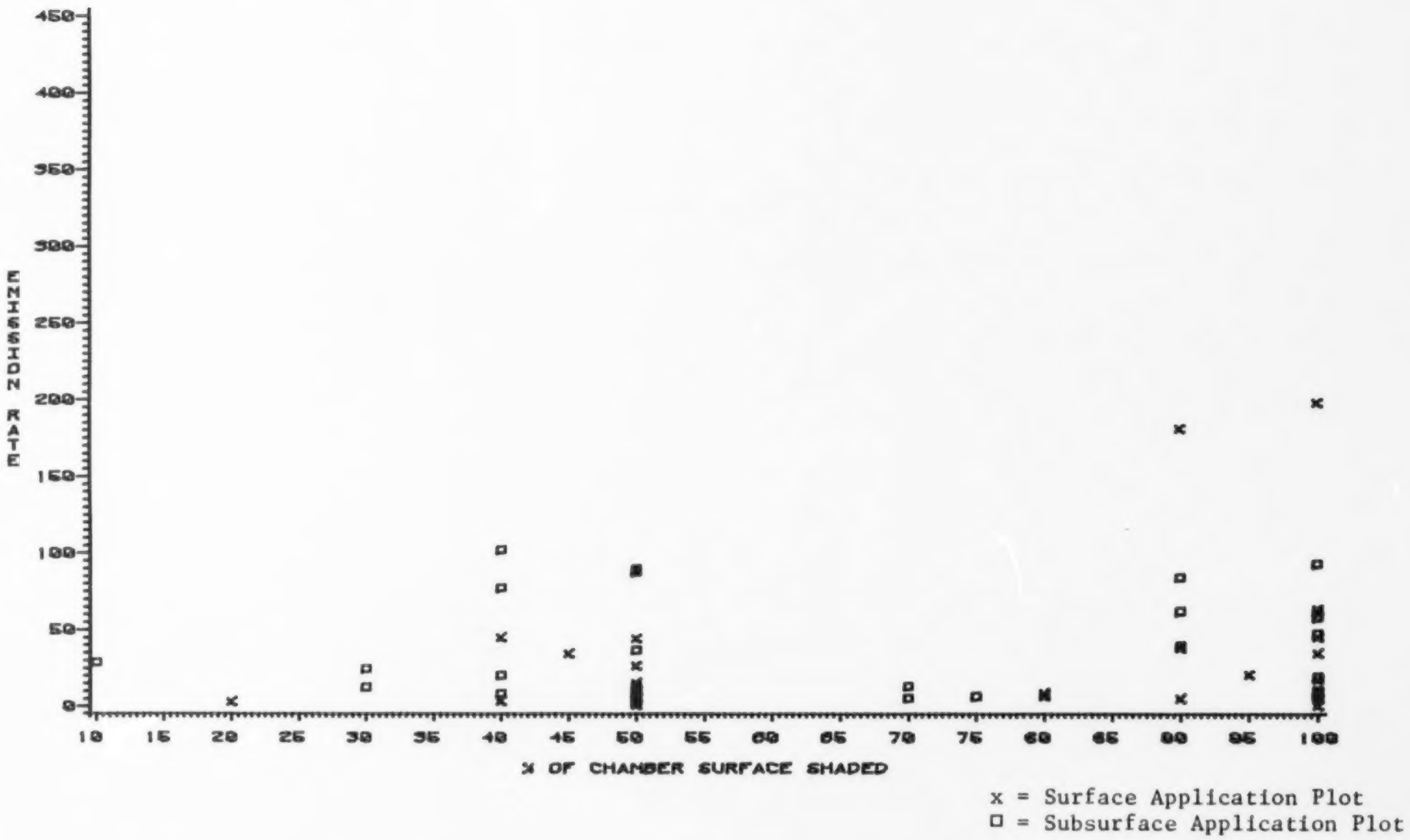


Figure 7. Measured emission rate (ug/m^2-sec) vs. air temperature inside the chamber.



x = Surface Application Plot
□ = Subsurface Application Plot

Figure 8. Measured emission rate (ug/m^2-sec) vs. % of chamber surface shaded.

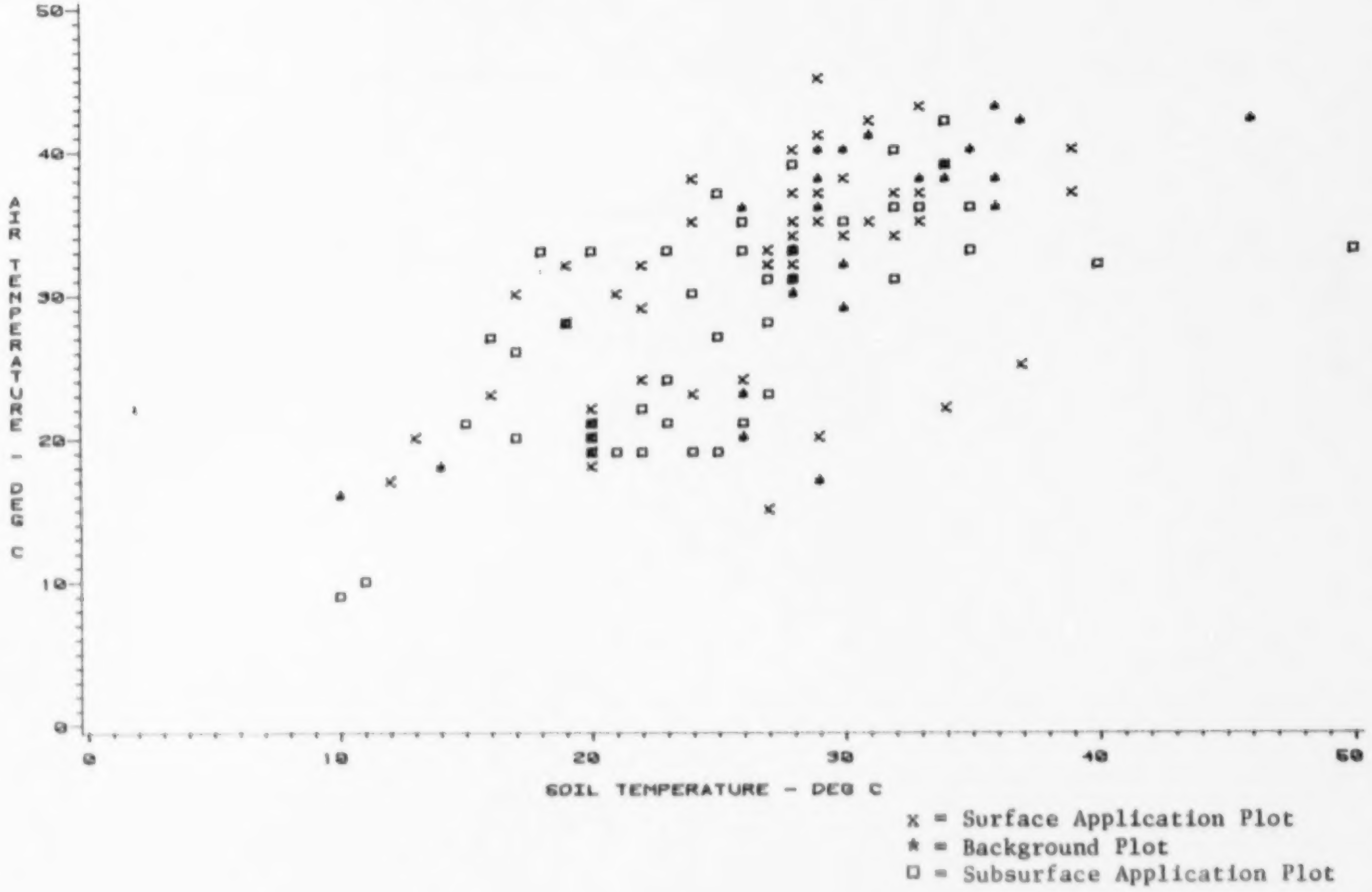


Figure 9. Chamber air temperature vs chamber soil temperature °C.

amount of emissions variability explained by the model (as determined by the square of the multiple correlation coefficient, R^2). 78% of the total emissions variability was explained when air temperature was used, while 77% was explained using soil temperature. Air temperature was chosen to use in further analyses because a more consistent temperature measurement is achieved and it is simply easier to measure.

The significance levels of the variables examined using the ANCOVA program are given in Table 15. The significance level indicates the confidence with which one can conclude that the parameter has a true, or repeatable, effect on emissions when the effects of the other parameters are removed. Time, chamber air temperature and test plot were statistically significant variables indicating a true, or repeatable relationship with measured emissions. Overall, measured emissions decreased exponentially over the five-week test period. Over the short-term (within a day), measured emissions increased with increased chamber air temperature. Figure 10 shows a plot of individual measured emission rates versus chamber air temperature for one of the sampling days. This day was selected because sampling was initiated before dawn and continued over a wide range of ambient air temperatures. This figure illustrates the positive correlation between temperature and measured emissions as was indicated by the ANCOVA results.

Table 16 presents adjusted mean measured emissions for each test plot, i.e., all data corrected to a given set of constant conditions. The adjusted average emission rate for each plot represents the approximate responses that would have been obtained if all measurements had been made at the same time (midway through the test program on October 21, 1984) with the same chamber air temperature (the overall average air temperature of 26.7°C) and the same number of measurements taken at each sampling location. The surface versus subsurface plot comparison shows the type of application did not have a large effect on measured emission rate levels; there is considerable overlap in their uncertainty distributions. A multiple comparison t-test was used to statistically compare the adjusted mean emission rates for the test plots. The average emission rate for the background plot (plot C) was significantly lower than the emission rates for the test plots with applied wastes. At the 95% probability level, the emission rate data does not indicate a significant difference between the surface and subsurface applied plots. The effect of test plot in the ANCOVA is primarily due to the lower emissions from the background plot.

The components of variability associated with the emission rate measurements are given in Table 17. Day-to-day temporal variability, which includes hour-to-hour variability, had by far the greatest effect on emission rates. Ninety-nine percent of the total emission rate variability is due to time, chamber temperature and test plot. Operator error, both sampling and analytical, was negligible.

Results from the ANCOVA were also used to develop a correction factor equation which can be used to correct the measured emission rate to temperatures outside the chamber. The following equation (of the form seen in

TABLE 15. SIGNIFICANCE LEVELS OF ANCOVA VARIABLES

Variable in ANOCOVA Model	Level of Significance[a]	Statistical Significance[b]
Time	0.0001	Yes
Air Temperature Inside the Chamber	0.0014	Yes
Surface Chamber Shading	0.528	No
Plot (or Treatment)	0.0001	Yes
Location (within the plot)	0.553	No

[a] The probability of error in concluding that the variable has a significant effect on emission rate.

[b] Based on the analysis of covariance results, does the variable have a significant effect on measured emission rate at the 95% probability level (=0.05)? Given a conclusion of a statistical difference, there is a 5% probability that we are wrong.

NOTE: No statistical significance does not necessarily mean that the variable has no effect on measured emission rate. It simply indicates that there was not enough evidence in the data to conclude a statistical significance.

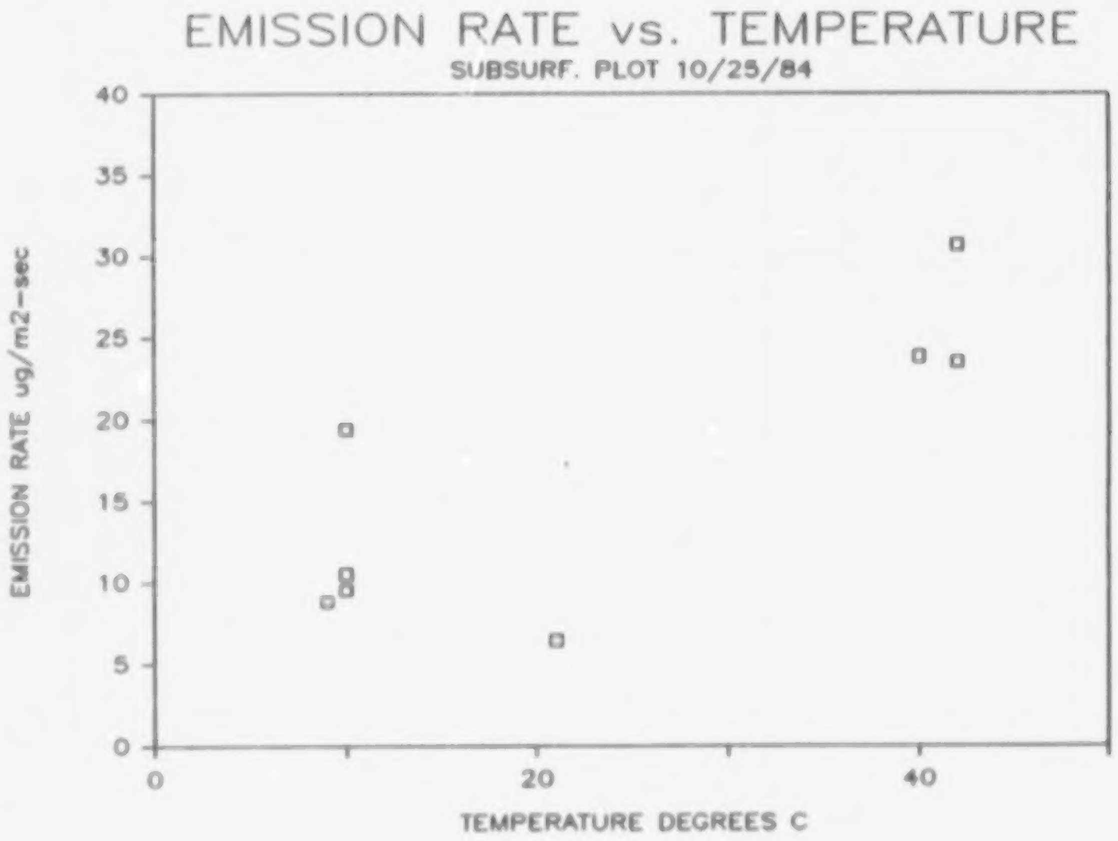


Figure 10. Measured emission rate vs. temperature for subsurface application plot on 10/25/84.

TABLE 16. SUMMARY OF ANALYSIS OF COVARIANCE RESULTS

Plot	Number of Data Points	Emission Rate (ug/m^2-s) Adjusted Mean[a]	Emission Rate (ug/m^2-s) 95% Confidence Interval
A (Surface Application)	48	23.3	(16.5, 32.7)
B (Background)	16	6.3	(3.8, 10.4)
C (Subsurface Application)	43	28.0	(19.6, 39.9)

[a] Mean emission rate levels were corrected for the concomitant variables (covariate) of time and air temperature in the chamber.

TABLE 17. COMPONENTS OF VARIABILITY

Source of Variability	Variance Component[a]	Percent of Total Variance	Percent of Total Minus Temporal Variance
Temporal (day-to-day)	85.6	81.8	-
Temperature Inside Chamber	8.4	8.0	44.1
Plot	9.6	9.2	50.4
Sampling Location (within the plot)	0	0	0
Surface Chamber Shading	0.29	0.3	1.5
Sampling/Analytical	0.75	0.7	3.9
Total	104.6	100	100

[a] Variance components are equal to standard deviations squared and thus have units which are the squares of that used for the log-emission rates $(ug/m^2\text{-sec})^2$.

Equation 8) was developed to predict emission rate as a function of time, chamber temperature, test plot, and sampling location within a plot:

$$ER = K \exp[-0.00384(TIME) + 0.0465(TEMP)] \qquad (11)$$

where, ER = emission rate,

K = constant dependent upon the test plot and sampling location within the plot,

TIME = elapsed time from application (hours), and

TEMP = air temperature inside the chamber (°C).

As determined by the square of the multiple correlation coefficient, R^2, 78% of the variability in the measured emission rates are explained by the terms in the equation (i.e., time, temperature, and sampling location).

Using Equation 9 for the correction factor and the above prediction equation for emission rate (Equation 11) the following correction factor, C, can be developed:

$$C = [\ \exp\ (0.0465)\ ]^{STEMP-ATEMP} \qquad (12)$$

$$= 1.0476^{STEMP-ATEMP}$$

where, STEMP = the standard air temperature (°C), and

ATEMP = the actual air temperature (°C).

The value C is a factor which can be used to correct the measured emission rate to a standard air temperature. To correct measured emission rate to air temperatures outside the chamber, the outside air temperature would become the standard air temperature used in Equation 12. For example, an emission rate of 10 ug/m^2-sec measured at a chamber air temperature of 30°C would be corrected to 6.3 ug/m^2-sec given an outside air temperature of 20°C [10 x 1.0474 = 6.3]. The increase in measured emissions caused by higher temperatures inside the flux chamber than outside the chamber is shown in Figure 11 for temperature differences ranging from 0°C to 20°C. The 95% confidence limits on the increase in emissions are based on the error associated with the temperature coefficient in Equation 11. This coefficient, 0.0465, has a standard error of 0.0139. The maximum measured difference between air temperature inside and outside the chamber for any given measurement was 18°C. Therefore, the predicted maximum increase in measured emissions caused by higher temperatures inside the chamber is 130% with a 95% confidence interval of (40%, 280%). The mean difference in temperatures inside and outside the chamber was 4°C, but the 95% confidence interval was quite wide (-6°, 14°).

It should be noted, however, that the above discussion and the resulting equation for correcting emission rates are based upon an unverified

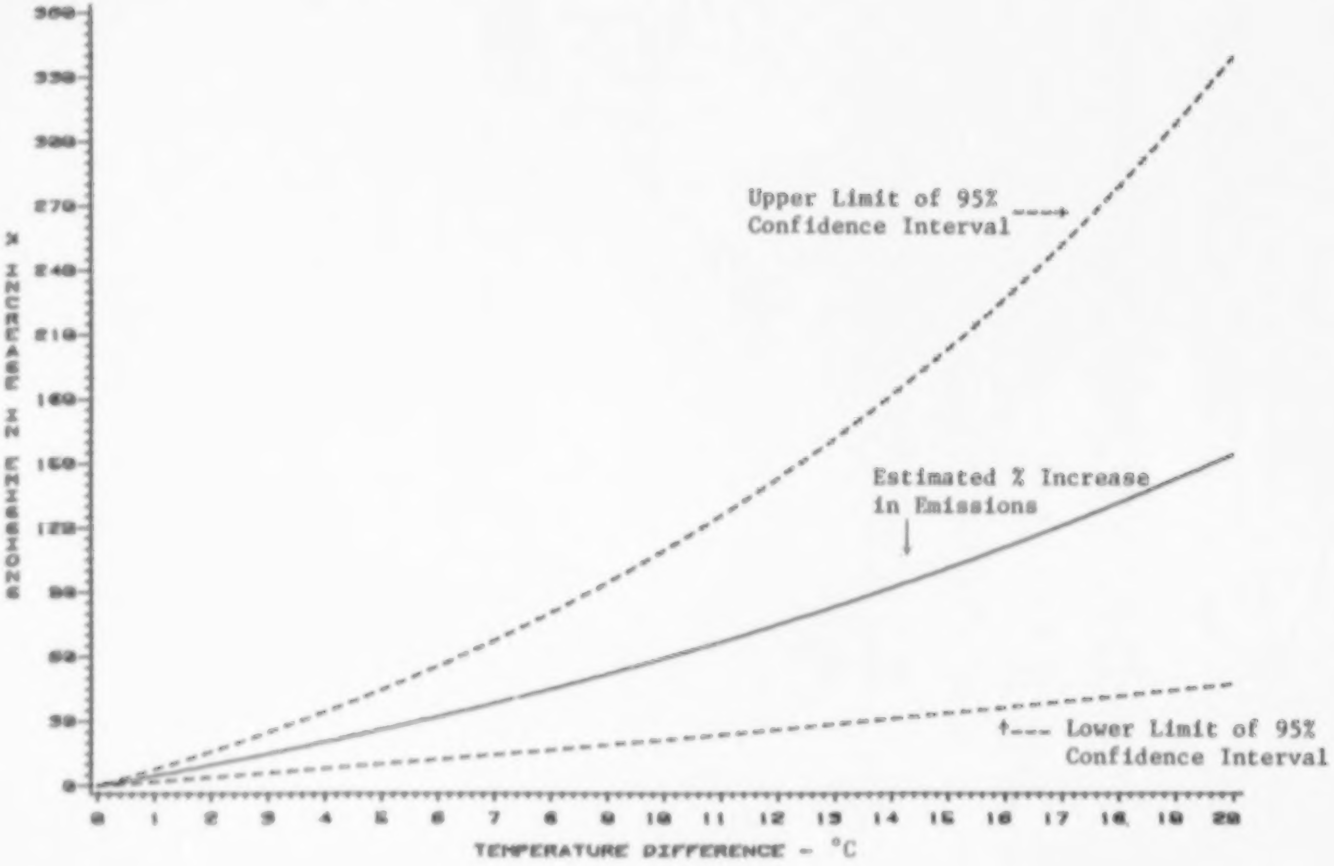


Figure 11. Percent increase in measured emissions due to an increase in air temperature.

assumption. The assumption is made that the emission rates measured inside the flux chamber at an air temperature T_F are equivalent to the rates occurring outside the chamber at the same ambient air temperature T_F. This assumption has, as yet, not been verified for land treatment systems, although it does appear to be valid for landfill-type systems in which organic vapors are transmitted through a soil bed which is uncontaminated with organic liquids (22).

A statistical analysis of Radian's soil oil content results was performed to see if there were significant differences in:

(1) The oil content of Plots A and C immediately after sludge application; and

(2) The oil content of the soil with time.

For each test plot, a linear regression analysis was performed in order to estimate the linear relationship between oil content and time. In order to complete the data base, a sampling time of 12:00 pm was assumed for the day in which the exact sampling time was not available. After the initial regression analyses were performed, outlier tests were conducted on the residuals from the results of the regression analysis. No outliers were identified. Slope estimates (change in oil content over time) from these regression analyses were tested for a significant difference from zero (null hypothesis of the slope equal to zero represents no change in oil or moisture over time). Slope estimates found to be different from zero were considered indicative of a linear trend in oil content over time.

The results of the statistical analyses are summarized in Tables 18 and 19. There was no statistically significant difference in the amount of oil applied to Plots A and C. Additionally, the oil content of the soil did not indicate a significant trend over time (at 95% confidence interval) for either plot.

TABLE 18. ESTIMATE OF OIL APPLIED TO PLOTS A AND C

			Oil Content (Wt %)[a]		Oil Applied (Wt %)[a]	
Plot	Sampling Episode	Number of Samples	Average	Relative Standard Deviation[b] (%)	Average	95% Confidence Interval
A	Initial[c]	1	4.90	2.04	1.02	(-4.16, 6.20)
	Following application	5	5.92	3.75		
C	Initial[c]	1	4.90	2.04	0.27	(-4.77, 5.31)
	Following application	3	5.17	2.71		

[a] Dry soil basis.

[b] Variability includes both within- and between-sampling location variability.

[c] Initial oil content of the soil in Plots A and C was assumed to be the same as that determined for the soil in Plot B.

TABLE 19. STATISTICAL SIGNIFICANCE OF OIL DISAPPEARANCE

Location	Week	# of Samples	Mean Oil Content (Wt %)	Standard Deviation (Wt %)	Difference (Wt %)	Standard Error of Difference (Wt %)	T-Statistic	Prob. [Diff]>0
A07	1	1	4.40	-	-0.20	-	-	-
	5	1	4.60	-				
A19	1	2	5.05	4.879	-2.05	3.456	-0.59	69.3
	5	2	7.10	0.283				
C11	1	1	3.40	-	-1.70	-	-	-
	5	1	5.10	1.556				
C15	1	1	5.40	-	0	-	-	-
	5	1	5.40	-				

SECTION 8

MEASURED EMISSION RATES AND EFFECTIVENESS OF VOC CONTROLS

This section presents measured emission rates for total volatile organics (as determined by GC) and for selected individual compounds. The biodegradation of organic compounds in the soil and the effect of application method on volatile organics emissions are also discussed.

TOTAL VOLATILE ORGANICS EMISSIONS

Total volatile organics emissions were examined with respect to elapsed time since application, ambient conditions at the time of sampling, and tilling activities. In addition, the measured total volatile organics emissions were extrapolated to provide an estimate of the total emissions for the entire five-week period after application.

Effect of Elapsed Time on Emission Rates

Emission rates were calculated as outlined in Appendix B from both the Byron (on-site, syringe samples) and Varian (off-site, canister samples) analytical results. The calculated emission rates are listed in Table 20. The average emission rates for Plots A, B, and C were 47.1 ±149% (31.3, 62.9), 6.16 ±106% (3.99, 8.33), and 53.9 ±163% (34.3, 73.5) ug/m^2-s, respectively. The variability given is the relative standard deviation and the values in parentheses are the 95% confidence interval about the mean. The Byron emission rates are reported as ug of benzene (the calibration gas used) and the Varian emission rates are given in terms of ug of the average molecular weight compound detected, which in this case is in the range of C_7 to C_8. As previously seen in Figure 4, the Byron and Varian analytical results were strongly correlated. Table 21 shows further evidence of the good agreement between the two analyses. Whenever a canister sample was taken in conjunction with each syringe sample, the average emission rates for half-day periods were strongly correlated (r = 0.9979) and showed little absolute difference (standard deviation = ±13.8%). The data for corresponding individual analyses also showed good agreement with r = 0.977 and an average difference of 2.3%.

Emission rates shown and used later in this section are from a combination of the Byron data and the Varian data. Whenever there is corresponding Byron and Varian data from the same test, these data have been averaged. On those days where the Byron data are known to be unreliable (see Section 10), the Varian data alone are reported (10/26 and 11/8-11/10). The average emission rates measured for each plot for each half-day of sampling are listed in Table 22. The relative standard errors (RSE) associated with the values in Table 22 are dependent on the number of measurements making up the

TABLE 20. COMPARISON OF BYRON AND VARIAN EMISSION RATES

SAMPLE ID	SAMPLING LOCATION	SAMPLING DATE	SAMPLING TIME	BYRON E.R. ug/m2-s	GAS CANISTER ID	VARIAN E.R. ug/m2-s	AVERAGE E.R. ug/m2-s	1/2 DAY E.R. AVG. ug/m2-s
C001	A19	10-9-84	1245	2.04			2.04	
C006	A09	10-9-84	1420	2.38			2.38	
C010	A02	10-9-84	1620	2.04			2.04	
C020	A07	10-9-84	1810	1.02	C021	1.129	1.08	1.88
C039	A19	10-10-84	1110	203.40	C040	269.028	236.21	
C045	A20	10-10-84	1145	236.79	C046	214.350	225.57	
C048	A07	10-10-84	1245	141.05	C049	186.723	163.89	
C055	A03	10-10-84	1328	350.92	C056	390.561	370.74	249.10
C064	A12	10-10-84	1505	196.92			196.92	
C072	A07	10-10-84	1550	180.23	C070+71	255.470	217.85	
C076	A19	10-10-84	1629	70.87	C075	113.329	92.10	
	A14	10-10-84	1752		C083	62.350	62.35	142.30
C084	A17	10-11-84	557	18.06	C085	21.038	19.55	
C091	A13	10-11-84	641	9.54	C092	14.108	11.82	
C097	A07	10-11-84	731	34.07	C096	46.056	40.06	
C099	A19	10-11-84	810	20.44	C100+D	16.420	18.43	22.47
C105	A07	10-11-84	925	48.72	C104	46.524	47.62	
C112	A19	10-11-84	1007	26.23	C113	35.556	30.90	
C121	A14	10-11-84	1132	34.41			34.41	
C125	A16	10-11-84	1208	17.38			17.38	32.58
C135	A19	10-12-84	950	26.57	C136	25.281	25.93	
C138	A14	10-12-84	1030	23.51			23.51	
	A07	10-12-84	1058		C141	130.572	130.57	
C145	A13	10-12-84	1136	12.61			12.61	48.15
C152	A07	10-12-84	1315	154.00	C153	183.006	168.50	
C157	A19	10-12-84	1402	143.78			143.78	
	A06	10-12-84	1440		C158	190.441	190.44	
C161	A12	10-12-84	1515	83.81	C162	82.433	83.12	146.46
C174	A19	10-13-84	839	14.99			14.99	
	A07	10-13-84	913		C175+6	28.999	29.00	
C178	A14	10-13-84	950	44.97			44.97	
C184	A13	10-13-84	1100	44.63			44.63	33.40
C186	A11	10-13-84	1142	43.95			43.95	
C192	A07	10-13-84	1352	37.82			37.82	
	A19	10-13-84	1425		C198	40.864	40.86	
C203	A06	10-13-84	1459	62.69			62.69	46.33
C213	A07	10-23-84	930	26.23			26.23	
C218	A11	10-23-84	1020	11.58			11.58	
C223	A19	10-23-84	1104	5.45	C224	4.443	4.95	
C233	A21	10-23-84	1235	17.38	C234	30.172	23.77	16.63
C236	A17	10-23-84	1316	23.51			23.51	
C238	A15	10-23-84	1355	15.67			15.67	
C239	A07	10-23-84	1440	16.01			16.01	
C244	A19	10-23-84	1515	6.13	C245	3.367	4.75	14.98
C254	A07	10-24-84	850	7.50	C255	4.722	6.11	
C260	A19	10-24-84	1000	6.81	C261	3.009	4.91	
C266	A16	10-24-84	1037	3.75			3.75	
C269	A15	10-24-84	1112	17.38			17.38	8.04
C271	A19	10-24-84	1306	12.95	C272	15.576	14.26	
C275	A07	10-24-84	1351	100.51			100.51	
C281	A12	10-24-84	1455	33.73	C280	26.441	30.09	
C283	A15	10-24-84	1532	48.04	C284	54.722	51.38	49.06

TABLE 20. (Continued)

SAMPLE ID	SAMPLING LOCATION	SAMPLING DATE	SAMPLING TIME	BYRON E.R. ug/m2-s	GAS CANISTER ID	VARIAN E.R. ug/m2-s	AVERAGE E.R. ug/m2-s	1/2 DAY E.R. AVG. ug/m2-s
C288	A19	10-25-84	538	2.38			2.38	
C291	A07	10-25-84	610	8.18	C292	9.429	8.80	
C296	A17	10-25-84	654	5.11	C297	5.415	5.26	
C305	A15	10-25-84	804	9.20			9.20	6.41
C309	A05	10-25-84	845	10.22	C310	9.173	9.70	
C315	A19	10-25-84	1229	7.84			7.84	
C318	A08	10-25-84	1300	17.38	C319	20.935	19.16	
C323	A07	10-25-84	1402	17.38			17.38	13.52
C330	A21	10-26-84	933	3.41				
C332	A07	10-26-84	1001	9.88	C331	21.852	21.85	
C338	A19	10-26-84	1034	0.68				
C340	A08	10-26-84	1103	4.77				21.85
C345	A07	10-26-84	1304	1.02	C346	176.788	176.79	
C351	A19	10-26-84	1340	9.54	C352+3	13.849	13.85	
C357	A16	10-26-84	1410	12.95	C354	22.749	22.75	
C363	A17	10-26-84	1515	14.31				71.13
C368	A03	11-8-84	942	1.36	C369	2.556	2.56	
C370	A01	11-8-84	1017	0.68				
C376	A19	11-8-84	1134	0.34				
C378	A07	11-8-84	1214	0.68				2.56
C382	A07	11-8-84	1244	0.34	C383	10.730	10.73	
C388	A12	11-8-84	1340	0.68	C389+90	3.766	3.77	
C393	A19	11-8-84	1425	0.00				
C401	A18	11-8-84	1536	0.00				7.25
C406	A07	11-9-84	912	0.00				
C414	A05	11-9-84	1027	0.68				
C417	A19	11-9-84	1101	0.34	C418	1.236	1.24	
C420	A01	11-9-84	1140	0.00				1.24
C425	A20	11-9-84	1323	0.00				
C427	A07	11-9-84	1402	0.00	C428	21.557	21.56	
C431	A19	11-9-84	1430	2.38	C432	3.122	3.12	
C439	A12	11-9-84	1543	0.34				12.34
C442	A11	11-10-84	940	0.20	C443	2.491	2.49	
C447	A07	11-10-84	1026	0.20				
C451	A19	11-10-84	1114	0.20				2.49
C455	A18	11-10-84	1202	5.52			5.52	
C464	A05	11-10-84	1340	6.54	C462	4.685	5.61	
C466	A07	11-10-84	1430	8.18	C467+68	7.940	8.06	6.40
C473	A17	11-12-84	756	3.41			3.41	
C477	A08	11-12-84	835	2.73	C478	2.947	2.84	
C481	A07	11-12-84	906	4.77			4.77	
C487	A19	11-12-84	1009	1.02	C488	0.713	0.87	2.97
C492	A07	11-12-84	1127	16.35	C493	22.281	19.32	
C497	A19	11-12-84	1201	4.77	C498	2.836	3.80	
C504	A21	11-12-84	1235	6.81			6.81	
C509	A20	11-12-84	1338	11.92			11.92	10.46
C002	B18	10-9-84	1245	1.70			1.70	
C004	B01	10-9-84	1325	2.04			2.04	
C005	B13	10-9-84	1420	0.34			0.34	
C008	B07	10-9-84	1515	3.07			3.07	1.79
C009	B08	10-9-84	1608	1.36			1.36	

TABLE 20. (Continued)

SAMPLE ID	SAMPLING LOCATION	SAMPLING DATE	SAMPLING TIME	BYRON E.R. ug/m2-s	GAS CANISTER ID	VARIAN E.R. ug/m2-s	AVERAGE E.R. ug/m2-s	1/2 DAY E.R. AVG. ug/m2-s
C014	B11	10-9-84	1705	1.36	C015	0.776	1.07	
C017	B04	10-9-84	1812	1.02	C018	0.641	0.83	
C023	B01	10-9-84	1855	1.36			1.36	1.16
C057	B06	10-10-84	1340	38.50			38.50	
C060	B12	10-10-84	1415	10.90			10.90	24.70
C077	B11	10-10-84	1655	7.15			7.15	
C078	B09	10-10-84	1709	12.95			12.95	10.05
C098	B06	10-11-84	800	4.43			4.43	
C101	B17	10-11-84	841	3.75			3.75	4.09
C120	B15	10-11-84	1057	4.77			4.77	
C126	B11	10-11-84	1220	5.45			5.45	5.11
C137	B09	10-12-84	1030	4.43			4.43	
C146	B16	10-12-84	1148	3.75			3.75	4.09
C165	B15	10-12-84	1536	18.06	C164	3.245	10.65	
C167	B18	10-12-84	1011	9.20			9.20	9.93
C179	B01	10-13-84	952	10.56			10.56	
C180	B02	10-13-84	1029	5.79			5.79	8.18
C190	B13	10-13-84	1153	12.95	C189	2.738	7.84	
C209	B11	10-13-84	1545	9.88			9.88	8.86
C219	B17	10-23-84	1033	2.73			2.73	
	B01	10-23-84	1150		C225	2.691	2.69	2.71
C235	B03	10-23-84	1322	5.45			5.45	
C249	B07	10-23-84	1553	6.81			6.81	6.13
C257	B06	10-24-84	925	1.70			1.70	
C270	B14	10-24-84	1123	3.75			3.75	2.73
C277	B13	10-24-84	1410	15.67	C278	14.153	14.91	
C278	B18	10-24-84	1423	5.11			5.11	10.01
C300	B20	10-25-84	730	2.04			2.04	
C303	B03	10-25-84	802	2.04			2.04	2.04
C314	B09	10-25-84	1226	4.09			4.09	
C321	B01	10-25-84	1335	7.50			7.50	5.80
C327	B14	10-26-84	903	1.70				
C328	B14	10-26-84	931	2.73	C329	1.324	1.32	1.32
C361	B06	10-26-84	1443	5.11				
C362	B03	10-26-84	1518	7.04				
C373	B16	11-8-84	1057	1.02				
C380	B19	11-8-84	1232	0.00	C381	2.590	2.59	2.59
C397	B11	11-8-84	1500	0.68				
C402	B18	11-8-84	1604	0.34				
C411	B03	11-9-84	947	0.34				
C421	B15	11-9-84	1140	0.00				
C436	B14	11-9-84	1507	0.34	C437	1.218	1.22	
C438	B03	11-9-84	1524	0.68				1.22
C456	B14	11-10-84	1209	2.04	C457	1.392	1.39	1.39
C459	B04	11-10-84	1248	1.43			1.43	1.43
C472	B01	11-12-84	752	1.02			1.02	
C491	B15	11-12-84	1040	1.36			1.36	1.19
C499	B13	11-12-84	1207	7.50	C500	4.740	6.12	
C506	B21	11-12-84	1306	2.73			2.73	4.42
C003	C11	10-9-84	1325	2.38			2.38	
C007	C03	10-9-84	1515	2.73			2.73	

TABLE 20. (Continued)

SAMPLE ID	SAMPLING LOCATION	SAMPLING DATE	SAMPLING TIME	BYRON E.R. ug/m2-s	GAS CANISTER ID	VARIAN E.R. ug/m2-s	AVERAGE E.R. ug/m2-s	1/2 DAY E.R. AVG. ug/m2-s
C011	C04	10-9-84	1700	1.36	C012	1.292	1.33	
C024	C01	10-9-84	1853	1.36			1.36	1.95
C037	C11	10-10-84	1105	147.86	C038	153.584	150.72	
C043	C15	10-10-84	1145	166.60	C044+D	196.850	181.73	
C050	C10	10-10-84	1255	305.61	C051	344.217	324.91	
C062	C19	10-10-84	1440	50.76	C063	41.729	46.25	175.90
C069	C09	10-10-84	1526	92.33	C067	115.252	103.79	
C073	C11	10-10-84	1615	77.00	C074	69.549	73.27	
C079	C15	10-10-84	1733	24.53	C080	22.877	23.70	
C082	C10	10-10-84	1816	10.22			10.22	52.75
C086	C11	10-11-84	600		C087	15.948	15.95	
C089	C15	10-11-84	645	2.73	C090	0.840	1.78	
C094	C07	10-11-84	725	12.27	C095	16.769	14.52	
C102	C09	10-11-84	845	20.10	C103	25.775	22.94	13.80
C106	C06	10-11-84	925	28.62			28.62	
C110	C15	10-11-84	1005	5.45	C111	1.253	3.35	
	C11	10-11-84	1046		C117+8	22.350	22.35	
C122	C17	10-11-84	1134	47.02	C123	56.485	51.75	26.52
C133	C01	10-12-84	950	101.87	C134	130.956	116.41	
C142	C11	10-12-84	1100	45.31			45.31	
C143	C15	10-12-84	1136	6.13			6.13	
C147	C03	10-12-84	1217	253.14	C148	367.806	310.47	119.58
C151	C15	10-12-84	1320	404.58	C154	556.837	476.02	
	C11	10-12-84	1401		C156	398.766	398.77	
C159	C05	10-12-84	1441	141.73			141.73	
C168	C13	10-12-84	1616	170.01	C169	157.686	163.85	295.09
C173	C01	10-13-84	831	36.45			36.45	
C177	C20	10-13-84	915	39.52			39.52	
C181	C15	10-13-84	1028	89.26	C182	154.225	121.74	
C185	C11	10-13-84	1115	87.22			87.22	71.23
C194	C13	10-13-84	1352	61.67	C195	68.138	64.90	
C201	C02	10-13-84	1420	57.92			57.92	
C204	C11	10-13-84	1503	60.99			60.99	
C208	C15	10-13-84	1545	83.47	C207	87.945	85.71	67.38
C215	C11	10-23-84	941	13.63	C216	20.006	16.82	
C222	C15	10-23-84	1106	8.18			8.18	
C227	C05	10-23-84	1150	14.99	C229	12.089	13.54	
C232	C02	10-23-84	1237	12.61	C231	9.468	11.04	12.39
C237	C18	10-23-84	1404	16.35			16.35	
C241	C11	10-23-84	1438	21.12			21.12	
C247	C19	10-23-84	1515	15.67			15.67	
C248	C15	10-23-84	1553	8.18	C250	6.596	7.39	15.13
C256	C15	10-24-84	857	6.81			6.81	
C258	C05	10-24-84	932	6.13			6.13	
C262	C11	10-24-84	1002	12.95	C263+4	15.890	14.42	
C267	C19	10-24-84	1048	12.95			12.95	10.08
C274	C01	10-24-84	1330	165.92			165.92	
C282	C13	10-24-84	1451	68.82			68.82	
C285	C11	10-24-84	1534	73.59	C286	89.163	81.38	
C287	C15	10-24-84	1615	49.06			49.06	91.29
C289	C11	10-25-84	540	9.54			9.54	
C293	C14	10-25-84	615	8.86	C294	8.711	8.78	

TABLE 20. (Continued)

SAMPLE ID	SAMPLING LOCATION	SAMPLING DATE	SAMPLING TIME	BYRON E.R. ug/m2-s	GAS CANISTER ID	VARIAN E.R. ug/m2-s	AVERAGE E.R. ug/m2-s	1/2 DAY E.R. AVG. ug/m2-s
C298	C15	10-25-84	655	10.56			10.56	
C299	C07	10-25-84	731	19.42	C301	19.268	19.34	12.06
C308	C19	10-25-84	843	6.47	C311	6.782	6.63	
C316	C15	10-25-84	1257	30.66	C317	37.043	33.85	
C320	C11	10-25-84	1330	23.85			23.85	
C324	C01	10-25-84	1403	23.51			23.51	21.96
C326	C13	10-26-84	900	6.81				
C333	C11	10-26-84	1005	5.45				
C336	C01	10-26-84	1036	7.15	C337	13.487	13.49	
C341	C15	10-26-84	1107	0.68	C342	12.461	12.46	12.98
C347	C11	10-26-84	1306	11.58	C348	74.100	74.10	
C350	C10	10-26-84	1337	24.19				
C356	C15	10-26-84	1408	31.69				
C359	C17	10-26-84	1435	1.70	C360	44.575	44.58	59.34
C371	C20	11-8-84	1042	0.68	C372	2.933	2.93	
C374	C15	11-8-84	1120	0.68				
C377	C08	11-8-84	1157	0.68				
C384	C11	11-8-84	1307	0.34				2.93
C391	C06	11-8-84	1350	0.34	C392	2.738	2.74	
C395	C15	11-8-84	1427	0.00	C396	8.788	8.79	
C398	C11	11-8-84	1502	1.36				
C400	C14	11-8-84	1536	0.34				5.76
C408	C11	11-9-84	929	0.00	C409	3.943	3.94	
C413	C13	11-9-84	1001	0.00				
C415	C14	11-9-84	1033	0.00				
C419	C15	11-9-84	1108	0.00				3.94
C423	C15	11-9-84	1313	0.34	C424	24.236	24.24	
C426	C11	11-9-84	1346	4.09				
C430	C04	11-9-84	1417	2.73				
C434	C06	11-9-84	1451	1.70	C435	8.070	8.07	16.16
C445	C05	11-10-84	946	0.20				
C448	C11	11-10-84	1033	0.00	C449	12.710	12.71	
C452	C21	11-10-84	1120	0.00	C453	10.270	10.27	11.48
C460	C15	11-10-84	1259	7.98			7.98	
C465	C07	11-10-84	1346	7.77	C463	7.354	7.56	
C470	C11	11-10-84	1435	5.11	C471	6.588	5.85	7.13
C475	C11	11-12-84	821	2.73			2.73	
C479	C15	11-12-84	850	2.73			2.73	
C485	C21	11-12-84	952	6.47			6.47	
C489	C01	11-12-84	1026	5.79	C490	2.803	4.30	4.06
C494	C05	11-12-84	1133	15.67	C496	14.602	15.14	
C502	C13	11-12-84	1236	14.65			14.65	
C510	C11	11-12-84	1305	16.01			16.01	
C511	C15	11-12-84	1338	17.38	C507+8	20.750	19.06	16.21

TABLE 21. CORRELATION OF BYRON VS. VARIAN EMISSION RATES[a]

Number of Byron Analyses per 1/2 day	Number of Varian Analyses per 1/2 day	Number of Data Inputs	Correlation Coefficient	Average[a] % Difference	Range (%)
3-4	4	4	0.9979	13.8	3.9-26.5
3-4	3	7	0.9727	22.6	-34.0-55.2
3-4	2	16	0.9366		
3-4	1	10	0.8352		
2	1	6	0.3267		

[a] Byron data for 10/25, 11/08, 11/09, and 11/10 AM not included. Averages shown are derived from the absolute value of the % differences.

TABLE 22. AVERAGE MEASURED EMISSION RATES BY PLOT BY HALF-DAY

Sampling Day	Date	Emission Rate (ug/m^2-s)			Comments
		A Plot (Surface)	B Plot (Background)	C Plot (Subsurface)	
0	10-9-84	1.88	1.48	1.95	
1	10-10-84	249	24.7	176	
	10-10-84	142	10.0	52.8	
2	10-11-84	22.5	4.09	13.8	early start
	10-11-84	32.6	5.11	26.5	
3	10-12-84	48.2	4.09	120	
	10-12-84	146	9.93	295	till
4	10-13-84	33.4	8.18	71.2	
	10-13-84	46.3	8.86	67.4	
5	10-23-84	16.6	2.71	12.4	
	10-23-84	15.0	6.13	15.1	
6	10-24-84	8.04	2.73	10.1	
	10-24-84	49.1	10.0	91.3	till
7	10-25-84	6.41	2.04	12.1	early start
	10-25-84	13.5	5.80	22.0	
8	10-26-84	21.8	1.32	13.0	
	10-26-84	71.1		59.3	till
9	11-8-84	2.56	2.59	2.93	
	11-8-84	7.25		5.76	
10	11-9-84	1.24		3.94	
	11-9-84	12.34	1.22	16.2	till
11	11-10-84	2.49	1.39	11.5	
	11-10-84	6.4	1.43	7.13	
12	11-12-84	2.97	1.19	4.06	
	11-12-84	10.5	4.42	16.2	till
					EACH PLOT AREA =4550 sq. ft. =423 sq. meters =0.104 acres

half-day average. For Plots A and C, the RSEs are 41.5, 33.9, and 29.4% for 2, 3, and 4 measurements, respectively. For Plot B, the RSEs are 28.9 and 20.5% for 2 and 4 measurements, respectively. During the average day of sampling, emission measurements were made over a seven-hour period. This was typically 9 AM to 4 PM. Sampling was begun at approximately 5:30 AM on two occasions to collect "nighttime" emission rate data, i.e., data at the coolest air and soil temperatures of the 24-hour day. The emission rates for the three plots are shown collectively in Figure 12 and individually in Figures 13 to 15. Results of the three measurement periods are plotted end to end; no data are presented for the periods between sampling efforts or for the parts of each day when sampling did not occur, i.e., at night. Each plot shows the same trend of decreasing emissions with time.

The cumulative emissions as a function of elapsed time for the actual measurement periods only are given in Table 23 and depicted in Figures 16 and 17. The relative standard deviations for the final values given in Table 23 are ±10.6, 8.64, and 10.6% for Plots A, B, and C, respectively. The values in Table 23 are based on a "1/2 day" of 3.5 hours. Cumulative emissions as a function of the applied volatile organics are shown in Figure 18. Figures 16 and 18 show the same trend of the subsurface application plot (C) having lower initial emissions than the surface application plot (A) but ultimately having greater total emissions. The lower initial emissions of plot C are thought to be a consequence of the application method, i.e., less exposed waste. The higher total emissions for plot C are (most likely) a result of sampling variability and differences in oil loading. For Figure 18, the application of waste mass to each plot is assumed to be equal. The validity of this assumption is discussed elsewhere in this subsection. The estimation of cumulative emissions for the entire test period after application are described below.

Effect of Tilling on Measured Emission Rates

Tilling had a large effect on the measured emission rates as evidenced by the large spikes occurring for tilling days on the emission rate versus time plots (Figures 12 to 15). In general, the magnitude of emissions for tilling days decreased with time, analogous to the overall trend of decreasing emissions with time. The exception to this trend is the subsurface application plot where the greatest emissions were measured immediately after the second tilling episode (first tilling after the day of application). This is thought to be a result of the application method. The waste was deposited several inches below the soil surface, and the initial tilling at the time of application only partially mixed the waste in with the soil. The next tilling increased the waste-soil mixing and caused more waste to be exposed at the surface, thereby increasing emissions. Subsequent tilling episodes may have also increased the mixing, but this effect was offset by the general decline in emissions with time.

It was observed that some waste was spread from the applied plots to the background plot whenever tilling was performed. This fresh waste was believed to be the cause of the increased emissions from the background plots. This opinion is derived from the average of all measurements at a

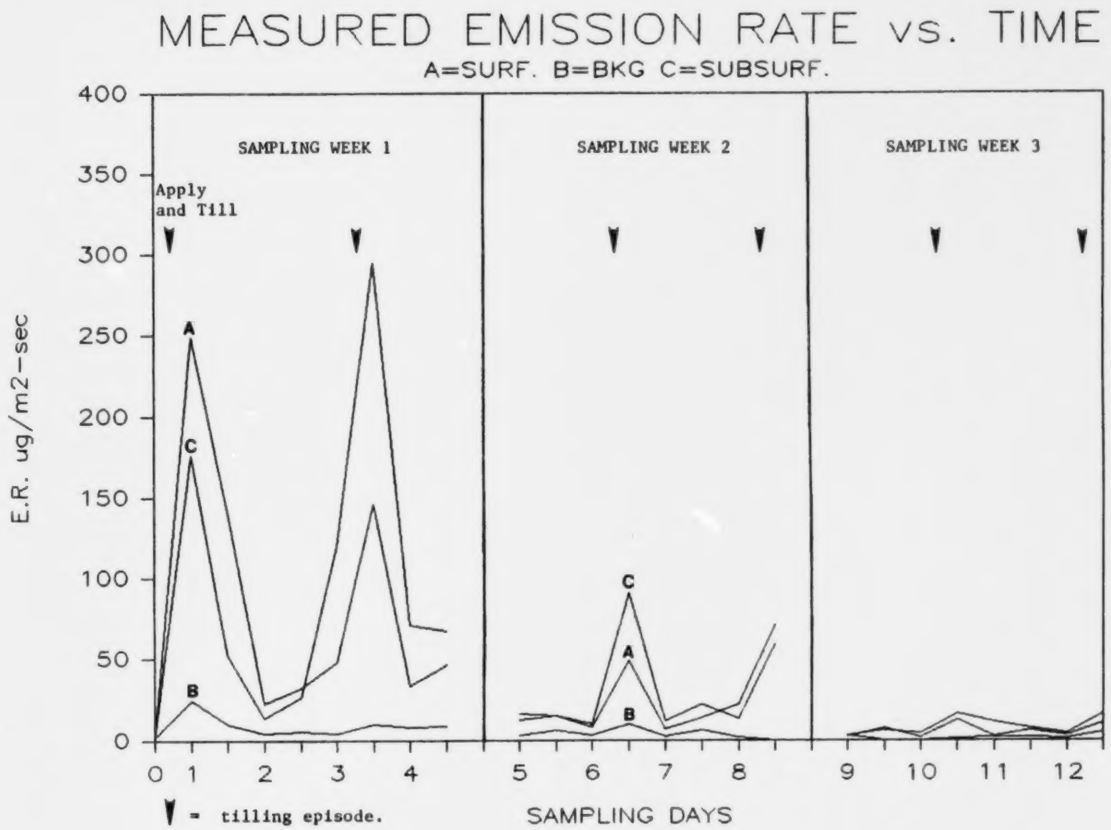


Figure 12. Measured emission rates vs. time for each plot.

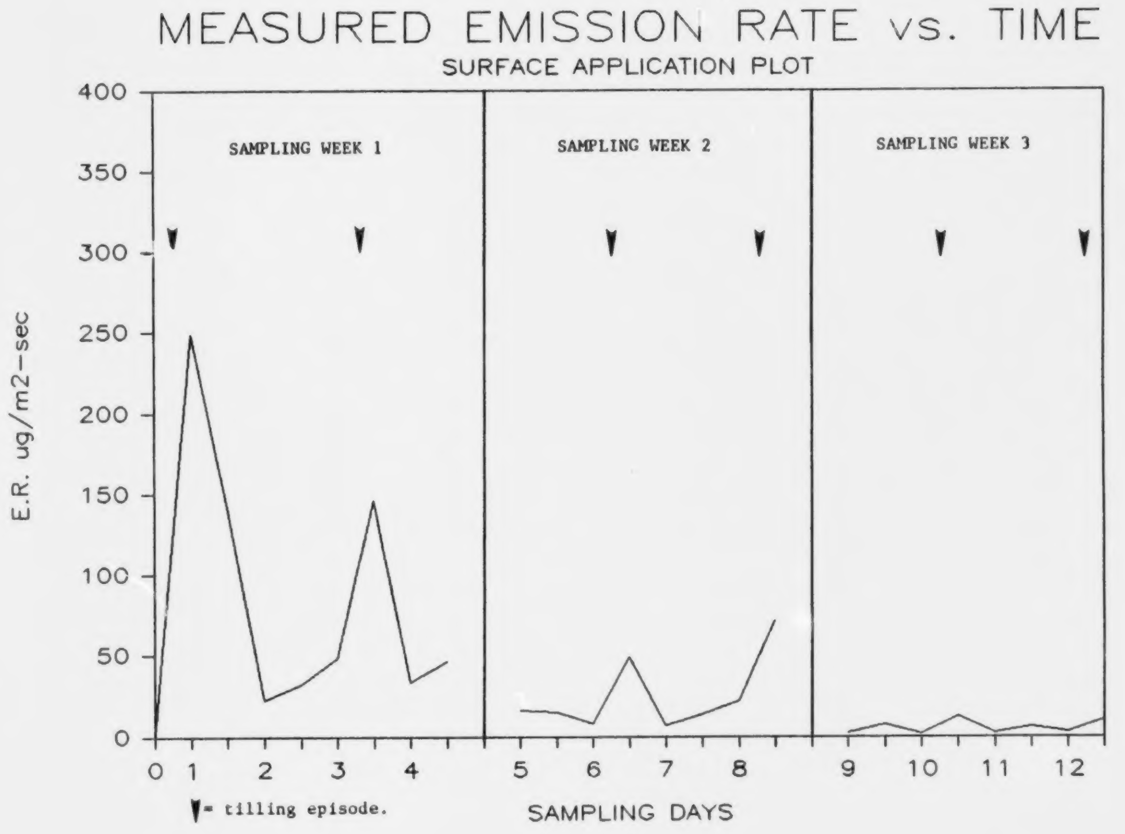


Figure 13. Measured emission rate vs. time for the surface application plot.

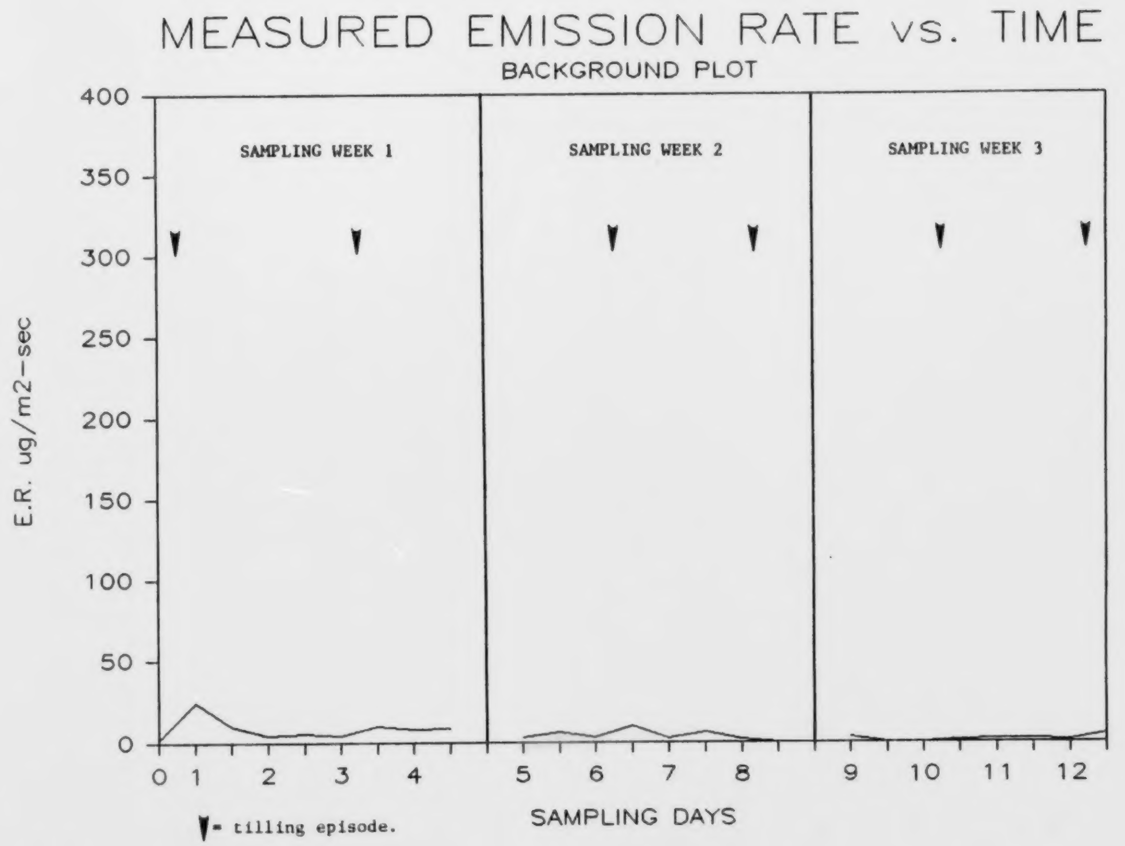


Figure 14. Measured emission rate vs. time for the background plot.

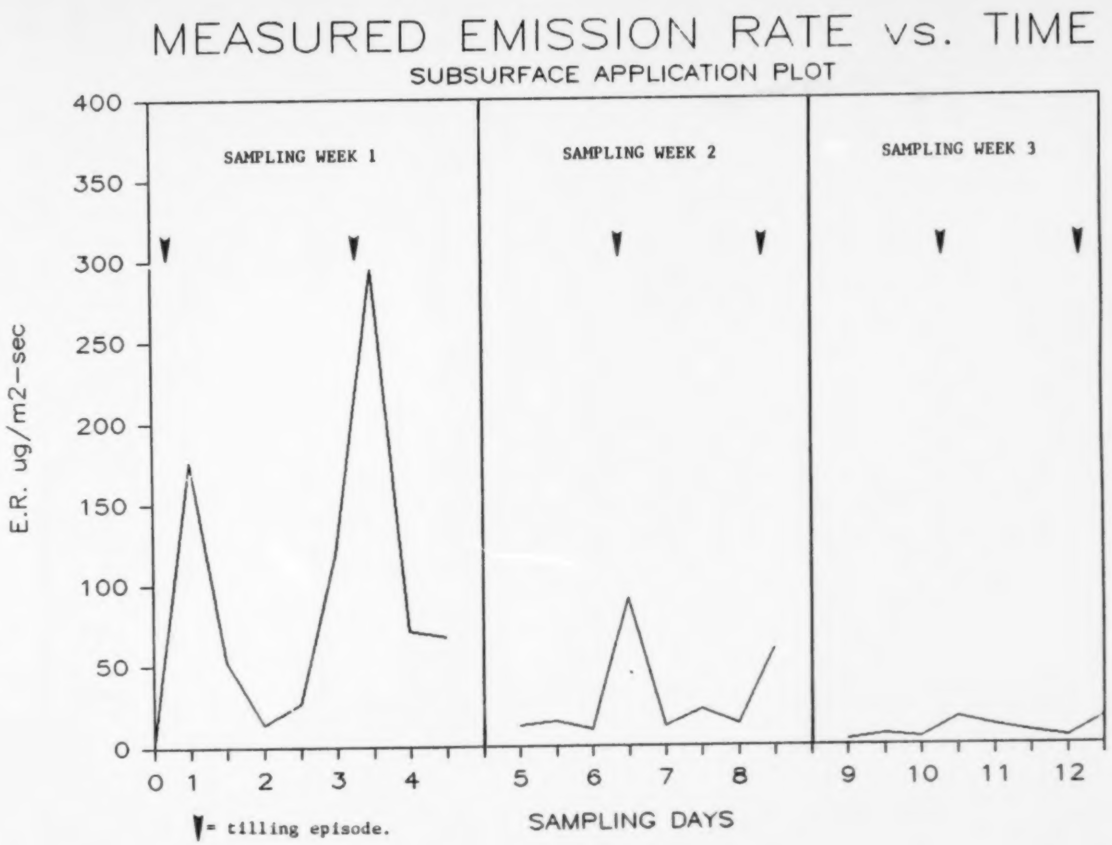


Figure 15. Measured emission rate vs. time for the subsurface application plot.

TABLE 23. CUMULATIVE MEASURED EMISSIONS

Sampling Day	Emission (kg) A Plot (Surface)	B Plot (Background)	C Plot (Subsurface)	Comments
1	1.327	0.1317	0.938	
	2.084	0.1850	1.219	
2	2.204	0.2068	1.293	early start
	2.378	0.2340	1.434	
3	2.634	0.2558	2.074	
	3.413	0.3088	3.646	till
4	3.591	0.3524	4.026	
	3.837	0.3996	4.385	
5	3.926	0.4140	4.451	
	4.006	0.4467	4.531	
6	4.049	0.4613	4.585	
	4.310	0.5146	5.072	till
7	4.345	0.5254	5.136	early start
	4.417	0.5563	5.254	
8	4.533	0.5634	5.323	
	4.912		5.639	till
9	4.925	0.5772	5.655	
	4.964		5.685	
10	4.971		5.706	
	5.036	0.5837	5.793	till
11	5.050	0.5911	5.854	
	5.084	0.5987	5.892	
12	5.100	0.6051	5.914	
	5.156	0.6286	6.000	till
				EACH PLOT AREA =4550 sq. ft. =423 sq. meters =0.104 acres

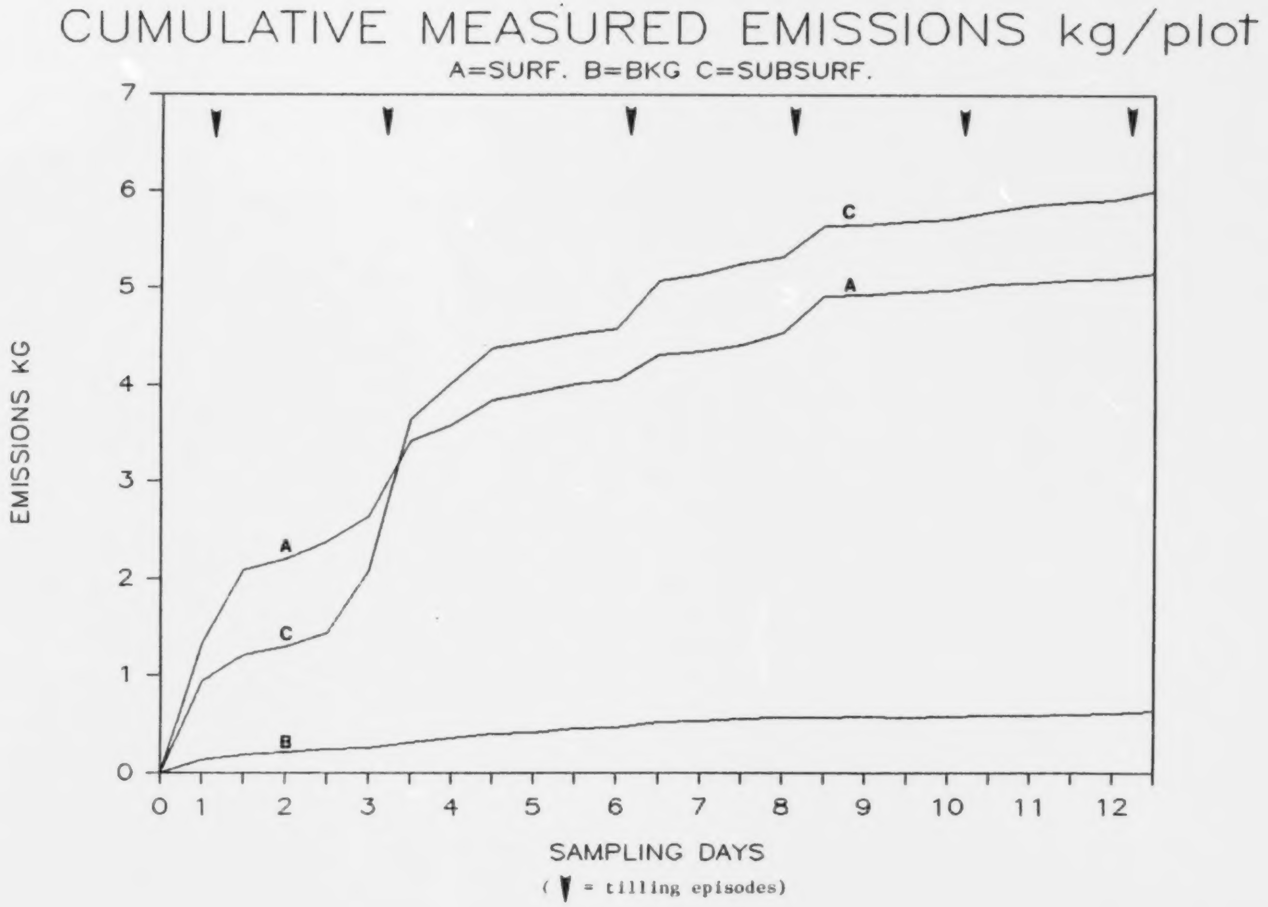


Figure 16. Cumulative measured emissions vs. time for each plot (only days on which sampling was done are shown).

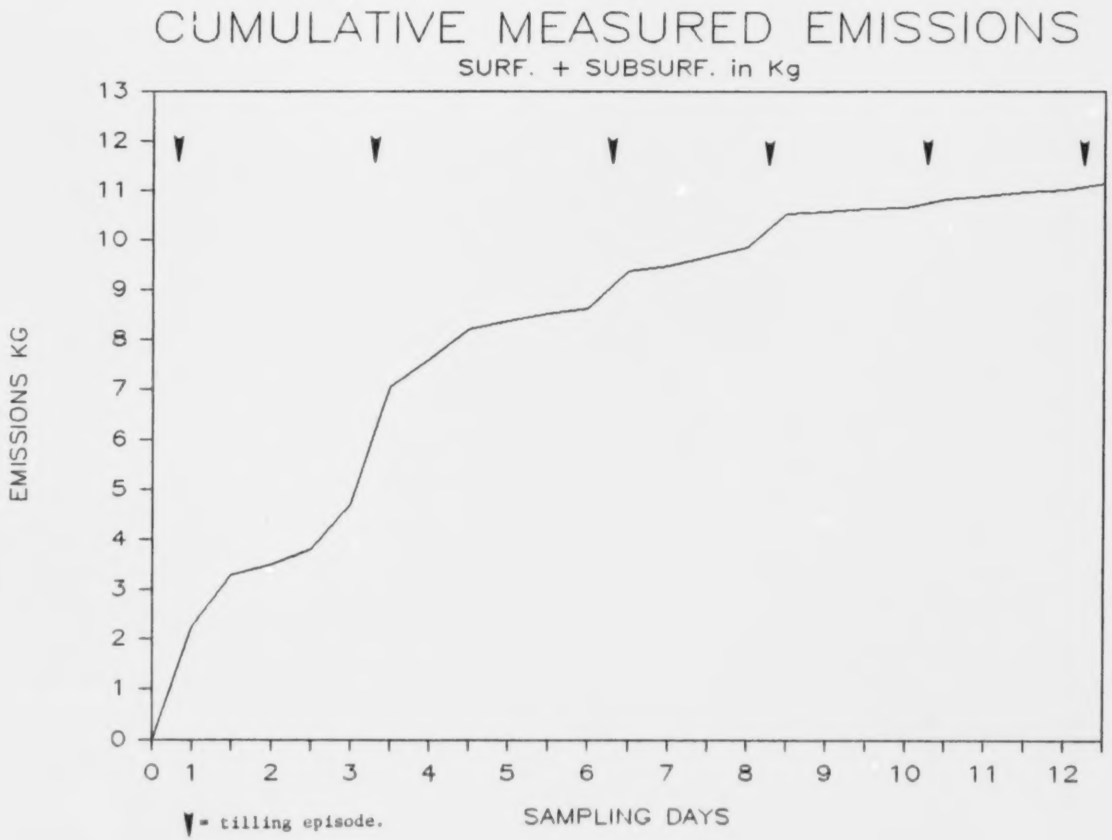


Figure 17. Cumulative measured emissions for the combined surface and subsurface application plots (only days on which sampling was done are shown).

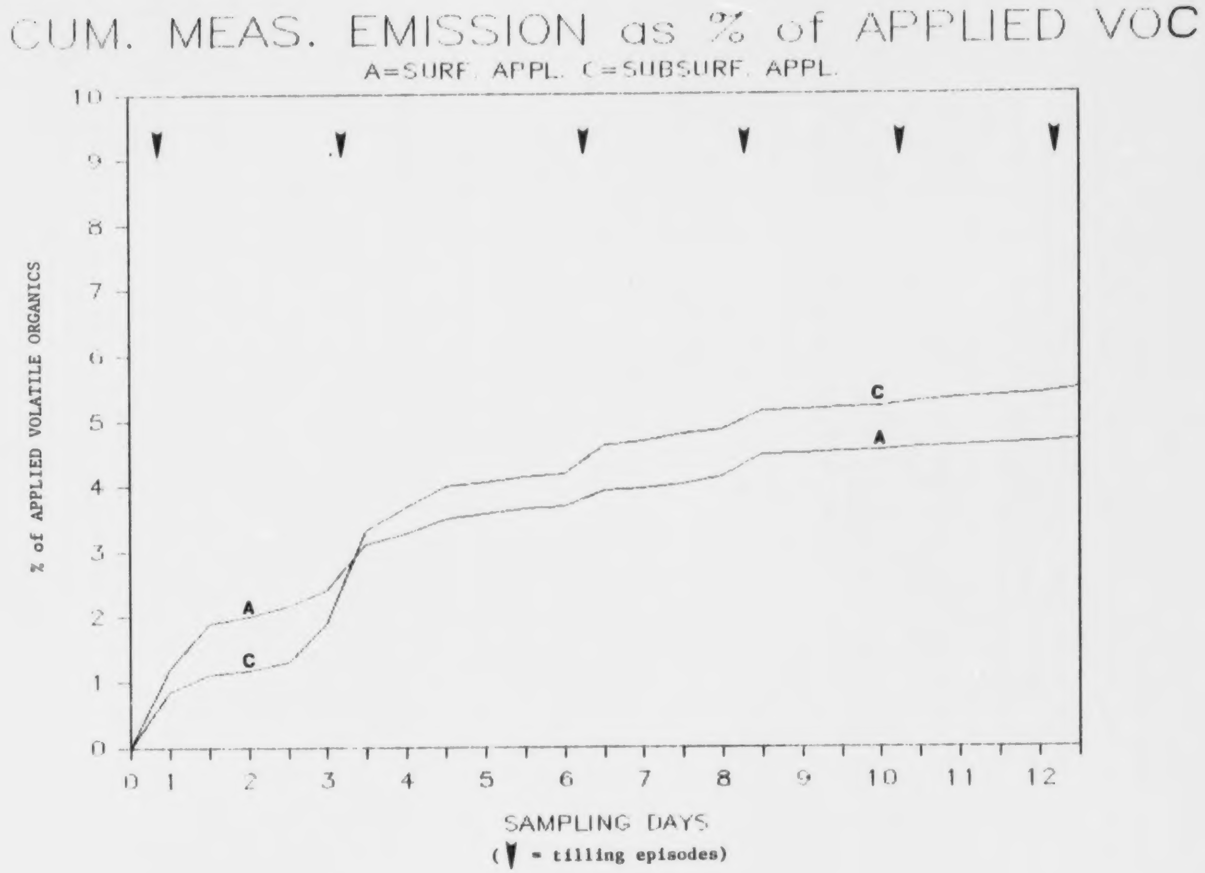


Figure 18. Cumulative measured emissions as the % of applied volatile organics (only days on which sampling was done are shown).

given gridpoint data (Appendix N), where gridpoints in the background plot that are adjacent to the other two plots show higher measured THC concentrations.

The percentage increase in average emissions by plot by half-day is given in Table 24 and depicted in Figure 19. The five sampling days that coincided with tilling events were spread out among the three sampling trips. The emissions increased from 143 to 895% due to tilling. This is significantly larger than the general trend of higher half-day emissions for afternoon versus morning periods due to temperature effects. Excluding the tilling days and the days where sampling commenced before dawn, the diurnal increase in emissions were +91% for Plot A (range = -9.64 to +183%), +46% for Plot B (+2.88 to +12.6%), and +19% for Plot C (-38.0 to +96.6%). There is no discernible trend in Figure 19 for the percent increase in emissions due to tilling versus time after application. All the individual emission rates measured for two of the tilling days are presented in Figures 20 and 21.

Estimated Emission Rate for the Test Period

The method used to estimate the total emissions from the land treatment plots for the five-week test period is presented in Appendix G and summarized below. In order to estimate the total emissions from each plot for the entire five-week testing period, the following assumptions were made:

- Tilling had no effect on emissions beyond 6 hours after tilling occurred; and
- Each day had 12 hours of cooler temperatures (night).

The night-time emissions were calculated from the emission rate data obtained during early morning hours. The tilling and non-tilling day emissions for the periods between sampling trips were derived by interpolation from the appropriate emission rate measurements. The resulting "best estimate" of total emissions per plot are given below. For comparison, total emissions based upon the average measured concentrations given in Table 12 are included. These would be expected to be somewhat higher than the estimated total emissions since the average is biased to daytime conditions since the majority of measurements were made then. The estimates agree with the cumulative measured emissions shown in Table 23 in that the total emissions from plot C exceed those of plot A.

	--Total Emissions--	
Plot	Best Estimate (kg)	Based Upon Average Measurement (kg)
A	33.3	60.2
B	5.20	7.88
C	39.0	68.9

TABLE 24. INCREASE IN EMISSION RATE DUE TO TILLING

Observed Tilling Episode	Percent Increase in Emission Rate					
	A Plot (Surface)	Relative Standard Error	B Plot (Background)	Relative Standard Error	C Plot (Subsurface)	Relative Standard Error
1	203	(62.1%)	143	(69.2%)	146	(69.9%)
2	511	(49.8%)	266	(56.4%)	804	(46.8%)
3	226	(64.6%)	0[a]		356	(75.3%)
4	895	(56.5%)	0[a]		311	(67.2%)
5	254	(57.9%)	271	(56.1%)	299	(55.5%)

[a] Insufficient data to calculate value

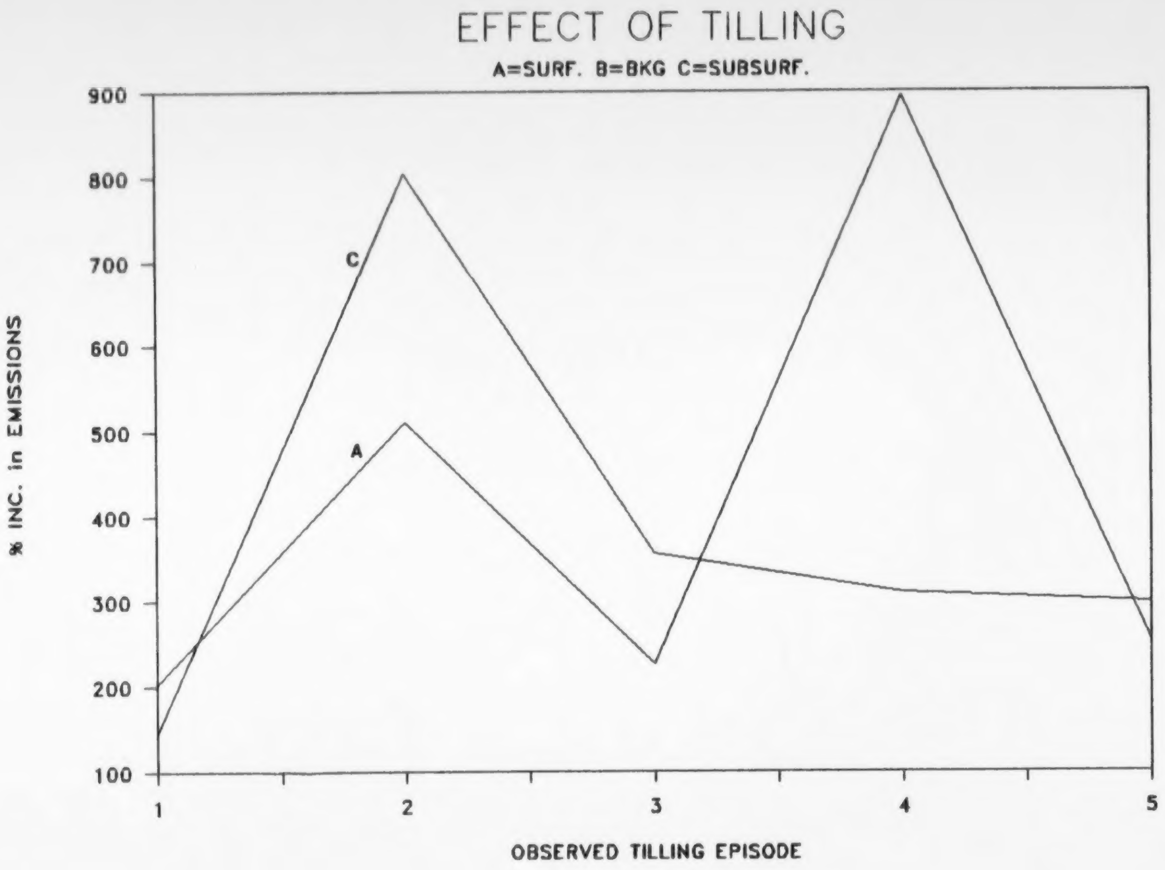


Figure 19. The percent increase in emissions following tilling by plot by half day.

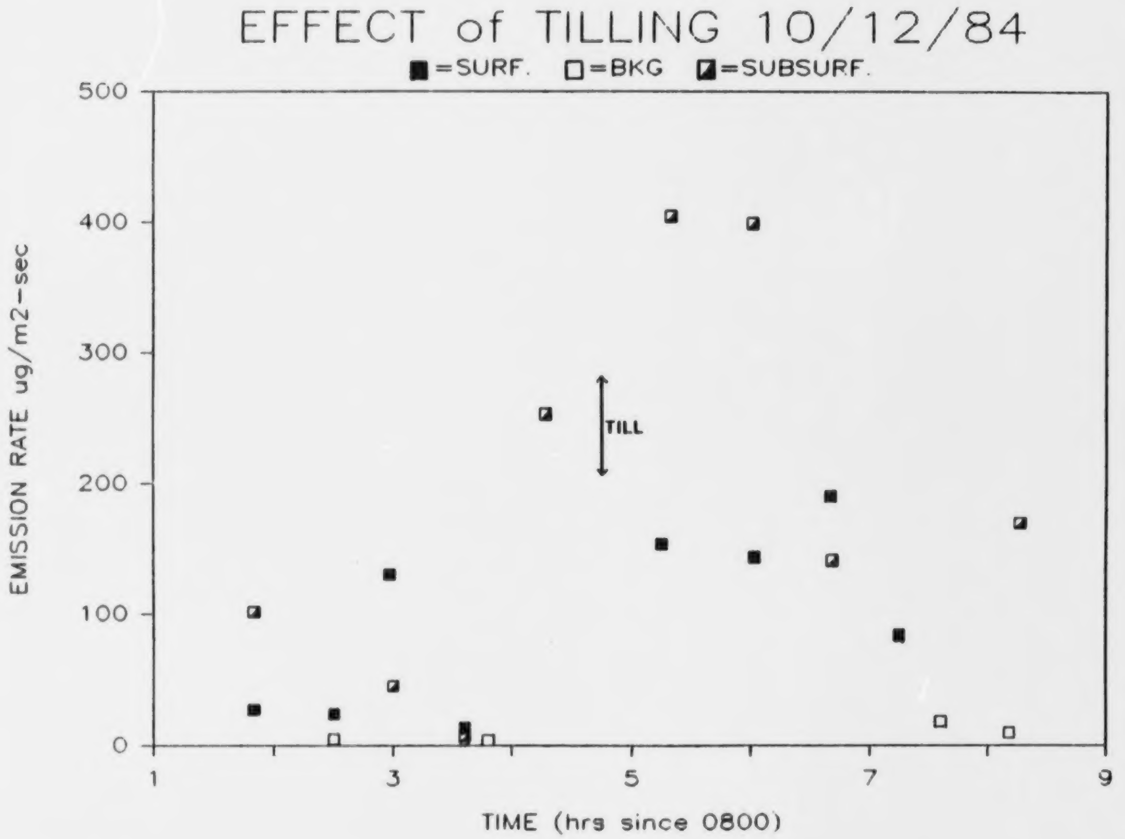


Figure 20. Measured emission rates for 10/12/84.

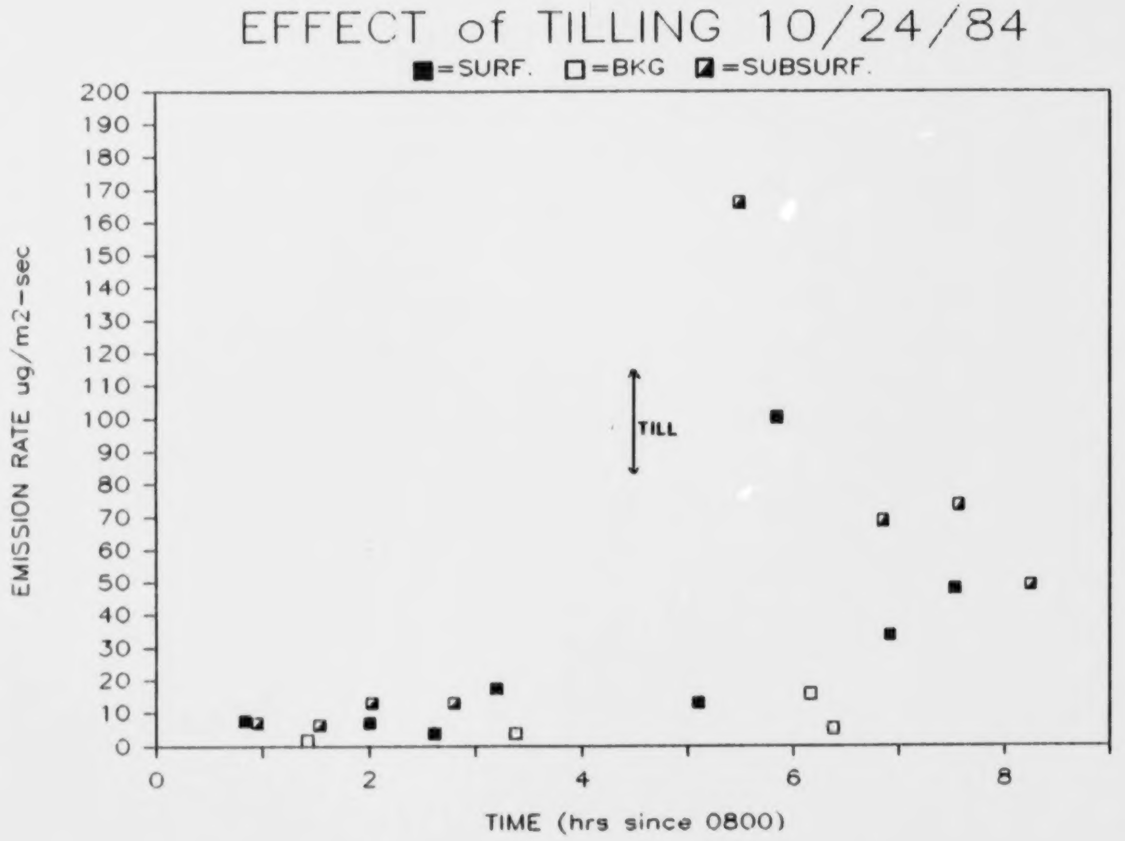


Figure 21. Measured emission rates for 10/24/84.

The estimated total emissions per plot per week are shown in Figure 22. The total estimated emissions for plot C exceed those for plot A for each of the five weeks. The emissions for each plot show a decrease with time. The cumulative estimated total emissions are shown in Figure 23 and again in Figure 24 as the percent of the applied volatile organics and in Figure 25 as the percent of the applied oil. The data used to generate these figures are given in Table 25. The assumption is made in Figures 24 and 25 that the volatile organics and oil loadings are equal for the two plots. Chevron had no capability for measuring the rate of application but attempted to spread waste as evenly as possible by controlling the speed and path of the application vehicle. Some differences in loading may have occurred due to differences in head pressure as the tank level and tine height varied. An increased resistance to oil flow out of the application lines during subsurface application may also have occurred. The assumption of equal loading is supported by the relative agreement between the % oil in soil analyses determined by Radian for the two plots given in Table 12 and the relative agreement between measured emission rates for different areas within the plots discussed in Section 7. While the cumulative emissions data for both total volatile organics and for individual compounds suggests the subsurface application plot received more waste than the surface application plot, Radian's data do not provide a basis for estimating the loading difference.

It is conceivable that the surface application plot had greater emissions during the first several days and nights after application than our estimates take into account and that this rapid initial depletion of volatile organics accounts for the differences seen over the remainder of the five-week study period.

EMISSIONS OF INDIVIDUAL COMPOUNDS

Included in this subsection are the selection criteria for the compounds examined, emission rates vs. time, the effect of tilling on emissions and estimated total emissions for the test period.

Selection of Compounds for Study

The gas canister analytical results were examined to determine the major compounds identified in each class of organic compounds over the duration of the emissions testing. Based upon this examination, four compounds in each of three classes (alkanes, alkenes, and aromatics) were selected for further data interpretation. Selection was made to include the major species emitting at both the onset and at the conclusion of testing. No examination of oxygenated or halogenated compounds was undertaken since halogenated compounds were present in relatively low concentrations and oxygenated compounds are not accurately measured by the analytical system used. The compounds selected are listed in Table 26. In this report, results are depicted for a relatively light compound in each class, n-heptane, 1-octene, and toluene; and for the heaviest compound in each class, n-nonane, limonene, and o-ethyltoluene. The other selected compounds exhibited similar behavior and are included in tabulated results.

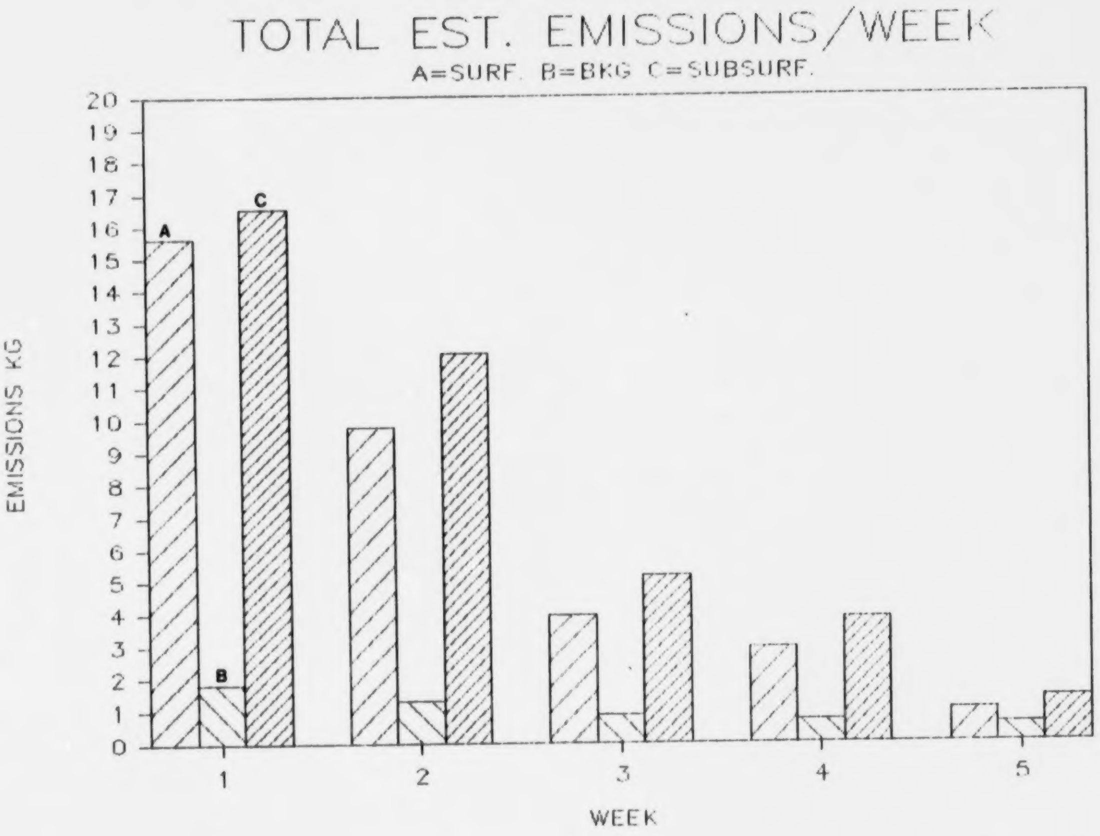


Figure 22. Total weekly estimated emissions for each plot.

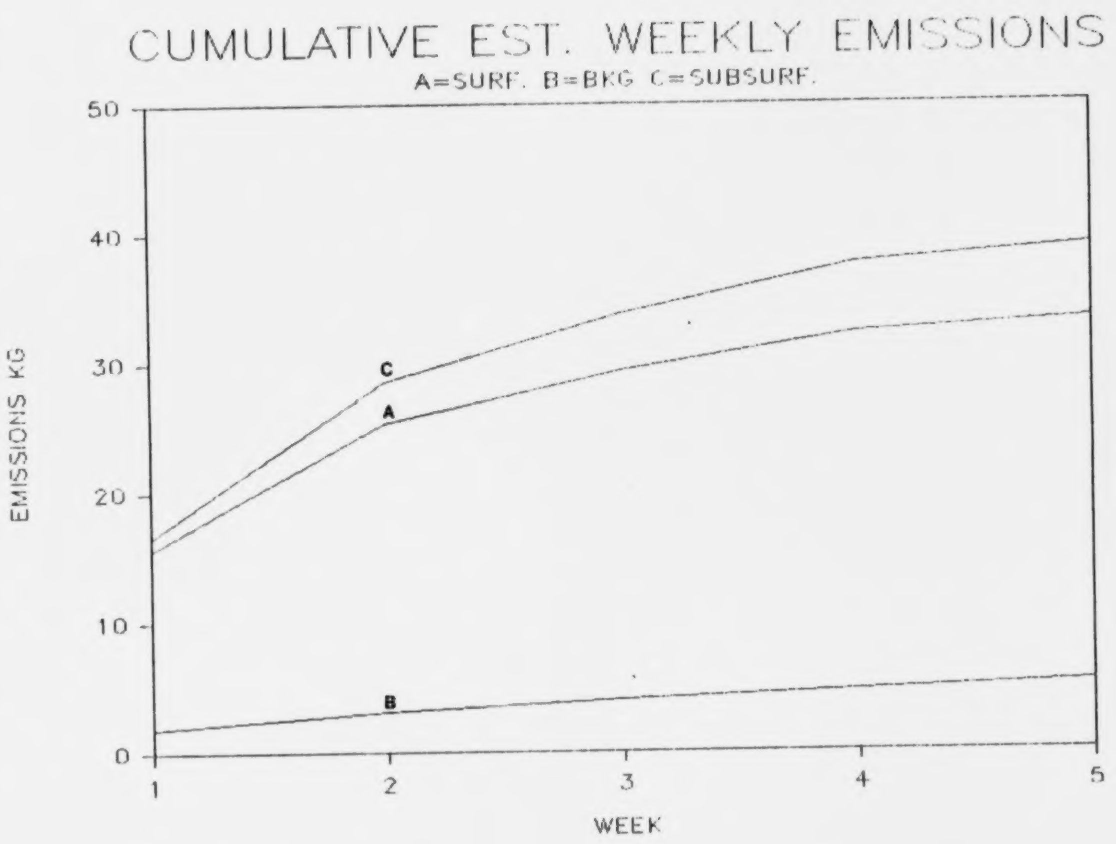


Figure 23. Cumulative estimated weekly emissions for each plot.

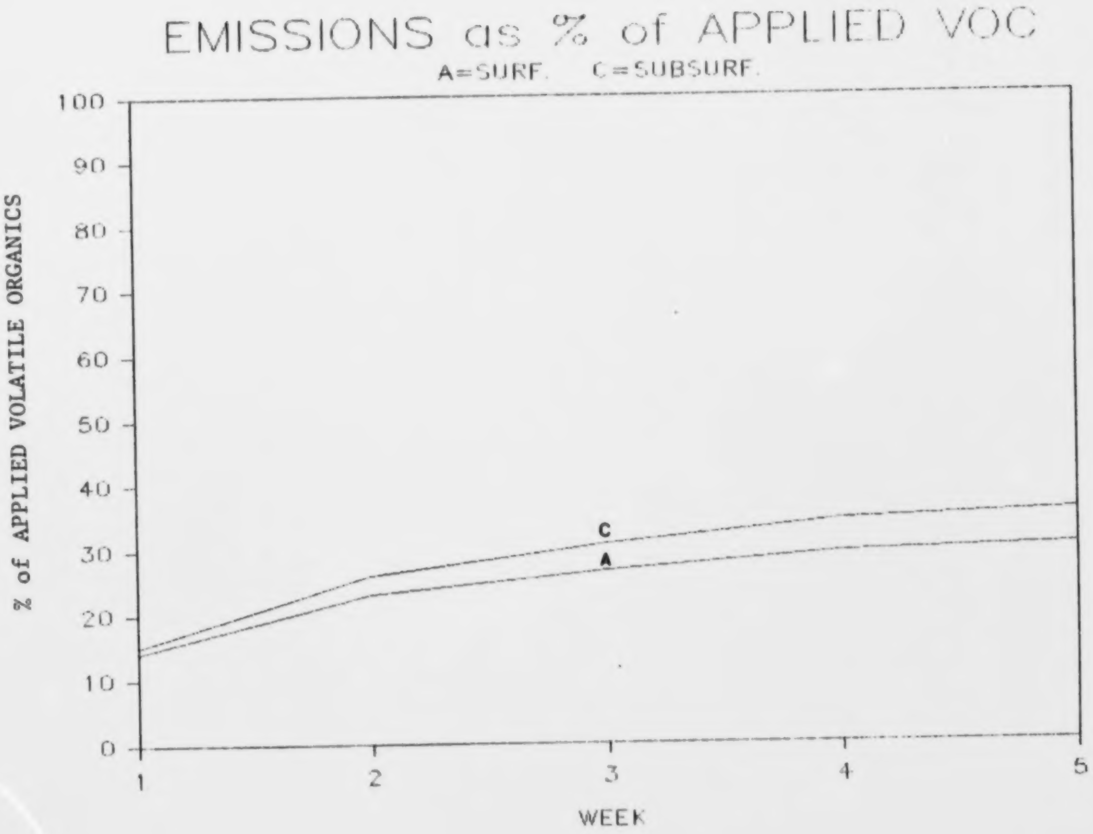


Figure 24. Total estimated weekly emissions as the % of applied VOC.

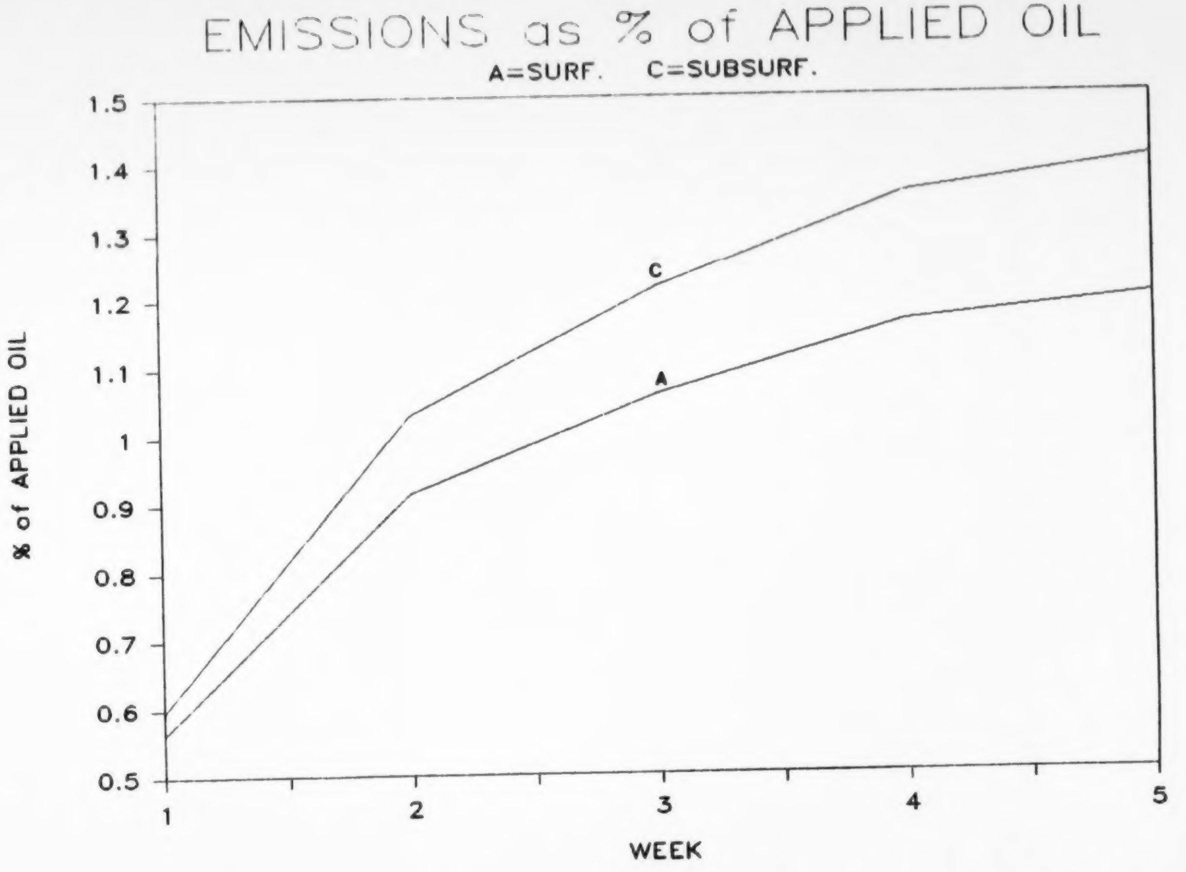


Figure 25. Total estimated weekly emissions as the % of applied oil.

TABLE 25. ESTIMATED TOTAL WEEKLY EMISSIONS

Plot	Week	Estimated Emissions (kg)	Cumulative Estimated Emissions (kg)	Cumulative Estimated Emissions Percent of Applied VOC	Cumulative Estimated Emissions Percent of Applied Oil
A - Surface Application	1	15.6	15.6	14.2	0.563
	2	9.76	25.4	23.1	0.916
	3	3.95	29.3	26.7	1.06
	4	2.94	32.3	29.4	1.16
	5	1.00	33.3	30.3	1.20
B - Background	1	1.82	1.82	-	-
	2	1.29	3.11	-	-
	3	0.838	3.94	-	-
	4	0.687	4.63	-	-
	5	0.564	5.20	-	-
C - Subsurface Application	1	16.5	16.5	15.1	0.595
	2	12.0	28.6	26.0	1.03
	3	5.16	33.7	30.7	1.22
	4	3.86	37.6	34.2	1.36
	5	1.37	39.0	35.5	1.41

TABLE 26. INDIVIDUAL COMPOUNDS SELECTED FOR FURTHER STUDY

Class	Compound
Paraffins	n-heptane
	methylcyclohexane
	3-methylheptane
	n-nonane
Olefins	1-methylcyclohexene
	1-octene
	B-pinene
	limonene
Aromatics	toluene
	p-xylene/m-xylene
	1,3,5-trimethylbenzene
	o-ethyltoluene

Effect of Elapsed Time on Emissions of Selected Compounds

The 1/2-day averages of the measured emission rates vs. time for n-heptane for the surface application plot, background plot, and subsurface application plot are presented in Figures 26, 27, and 28, respectively. The same data are shown for 1-octene in Figures 29 to 31 and for toluene in Figures 32 to 34. Similar plots are presented for n-nonane in Figures 35 to 37, for limonene in Figures 38 to 40, and for o-ethyltoluene in Figures 41 to 43. Table 27 presents the 1/2-day averages of measured emission rates for all 12 compounds examined. The relative standard errors (RSEs) associated with the values in Table 27 are dependent on the number of measurements comprising the half-day average. For Plots A and C, the RSEs are 68.6, 48.5, 39.6, and 34.3% for 1, 2, 3, and 4 measurements, respectively. For Plot B, the RSEs are 29.4 and 20.8% for 1 and 2 measurements, respectively.

For each compound, the emission rate generally increases after tilling, decreases to a low level by the end of the test period, and for the subsurface application plot does not reach a maximum until the plot is tilled two days after application. This same trend was observed for total volatile organics emissions. The cumulative measured emissions of the selected compounds for the test period are given in Figures 44 through 49. Each plot mimics the trend exhibited by the cumulative measured emissions for total organic compounds. The cumulative emissions for each compound as a percentage of the applied quantity of that compound are shown in Figures 50 to 55. Cumulative emission data are given in Table 28. The relative standard error for cumulative emissions is 15% and for the percent of the applied compound is 33% (all 12 compound and 3 plots pooled). The cumulative emissions for each compound examined are greater for plot C than for plot A. This tends to support the idea of unequal waste loading between the plots. The cumulative emissions of the individual compounds as a percentage of the applied material are in many cases of greater magnitude than the approximately 5% of total volatile organics emitted. This is believed to be due to the lighter molecular weights and hence greater volatility of the individual compounds versus the "average" molecular weight of volatile organics present in the sludge. No determination of the average molecular weight of the volatile organics in the sludge was made, but an examination of the sludge analyses (Appendix L) shows that the majority of compounds present (including unidentified species) are of 10 carbon atoms or more. Therefore, the sludge was of higher average molecular weight than the C_7 to C_9 compounds examined.

Effect of Tilling on Emissions of Selected Compounds

The large effect of tilling on emission rates during sampling weeks 1 and 2 is obvious from the previously shown plots of emission rate vs. time. The percent increases in emissions due to tilling for each of the lighter compounds are shown in Figures 56 to 58. Similar large increases in emissions due to tilling were observed for each of the other compounds, as seen in Table 29. The percent increases in emissions for the individual compounds

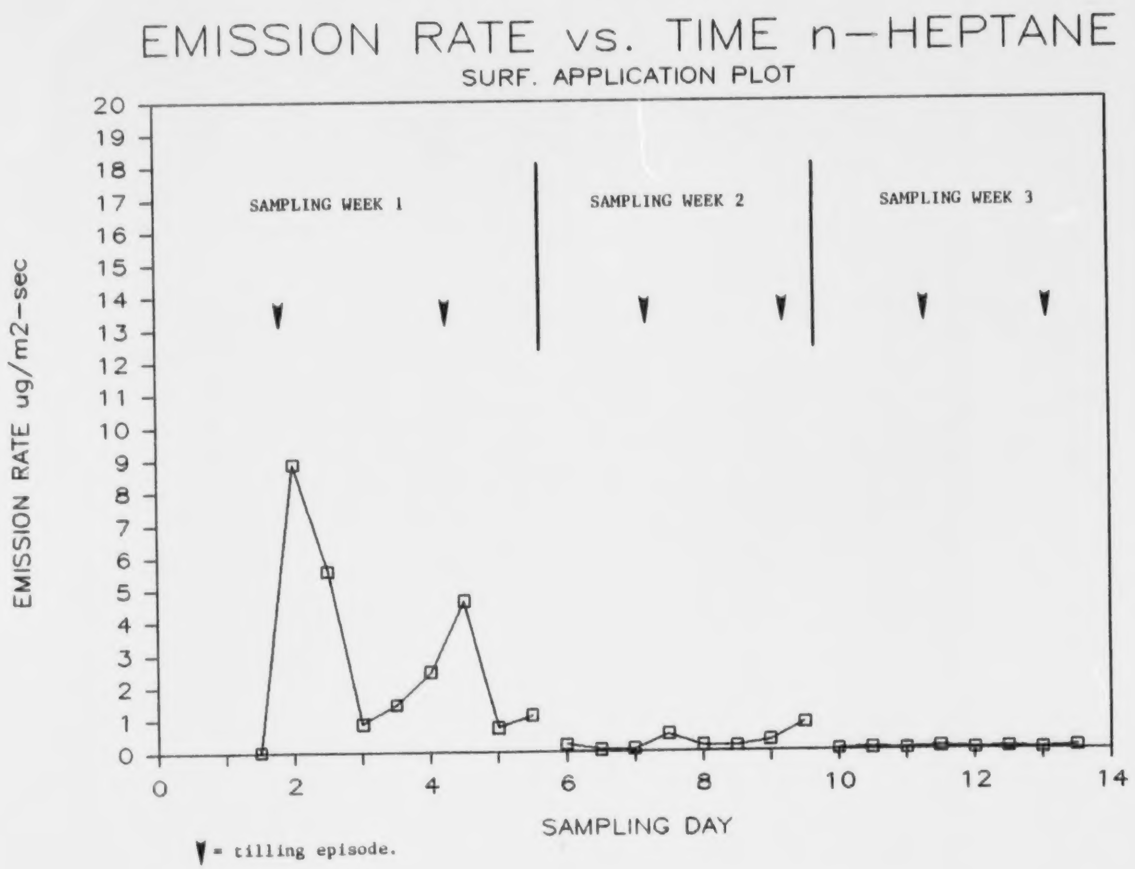


Figure 26. Emission rate vs. time for Plot A, n-heptane (only days on which sampling was done are shown).

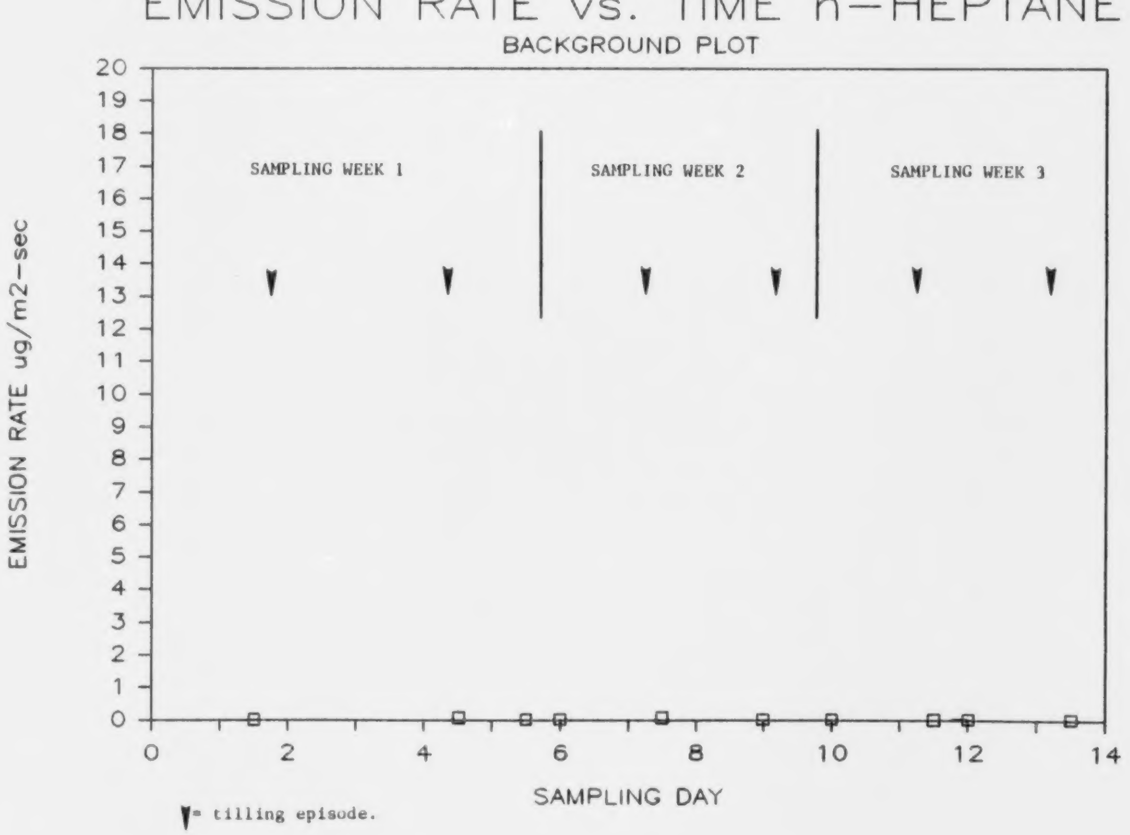


Figure 27. Emission rate vs. time for Plot B, n-heptane.

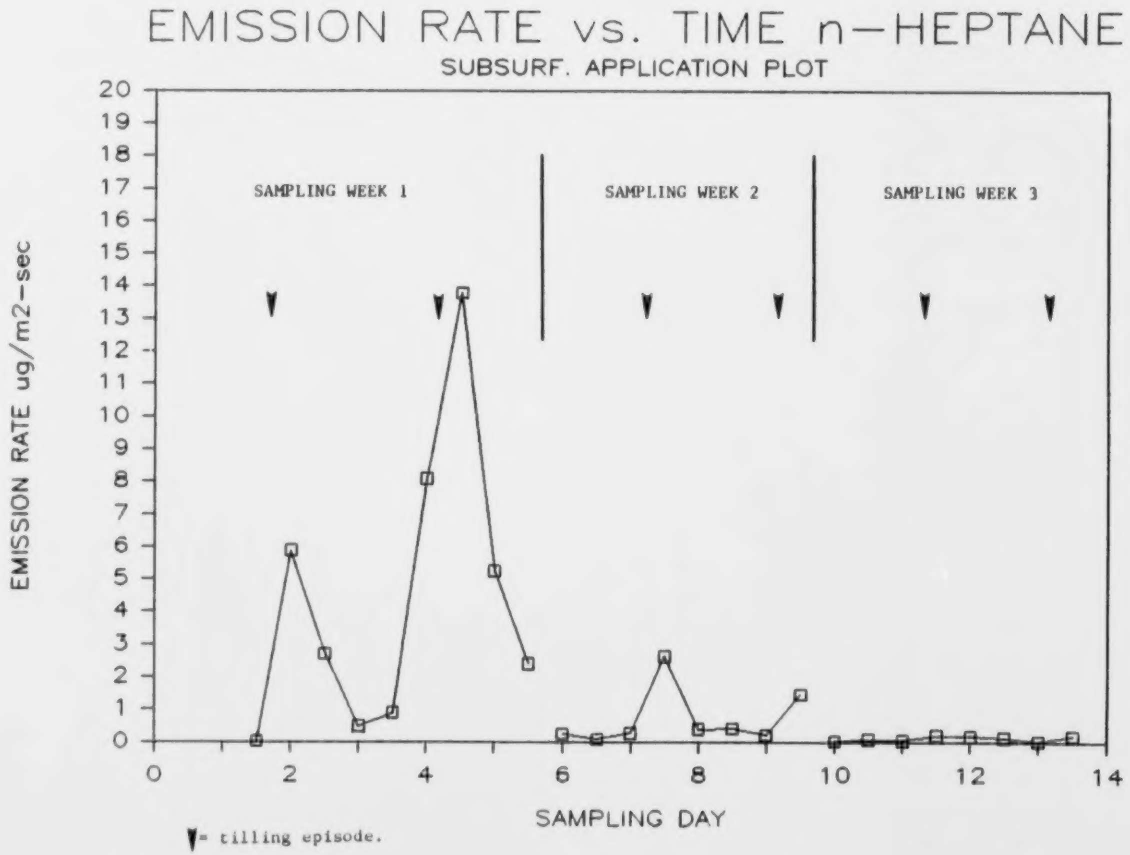


Figure 28. Emission rate vs. time for Plot C, n-heptane.

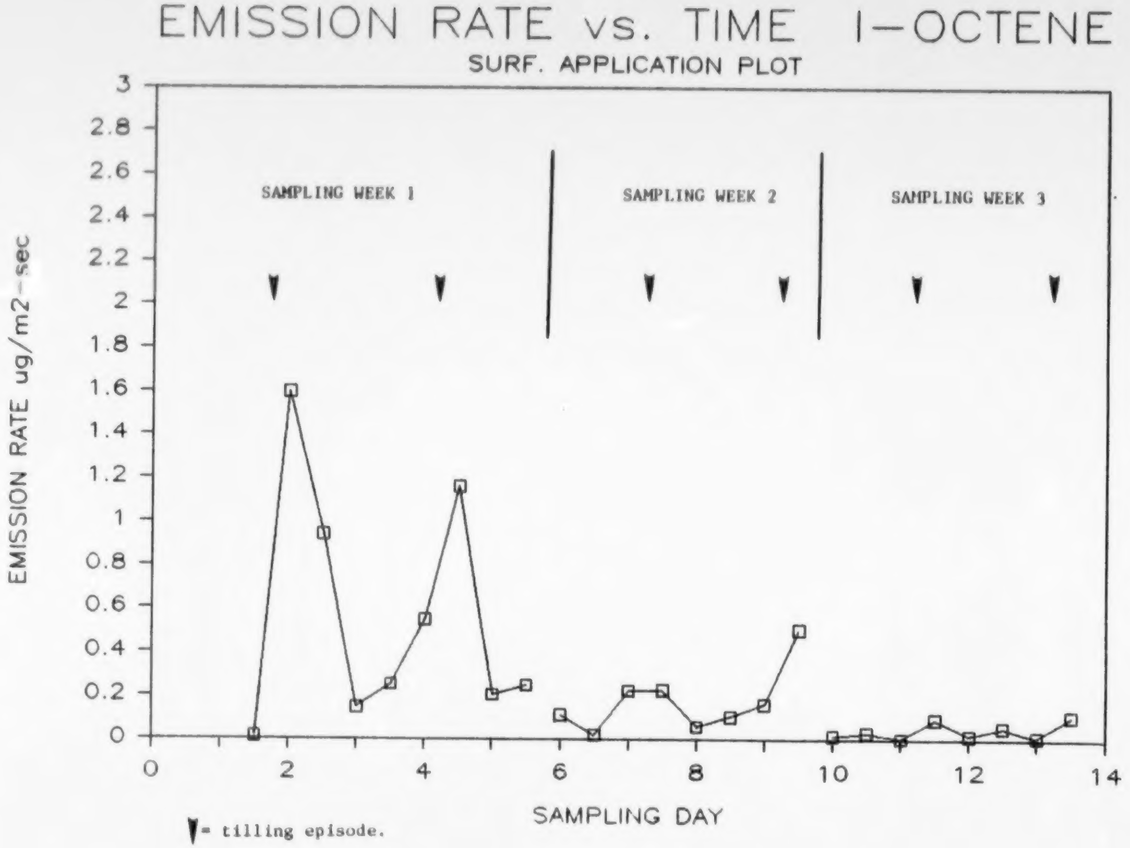


Figure 29. Emission rate vs. time for Plot A, 1-octene.

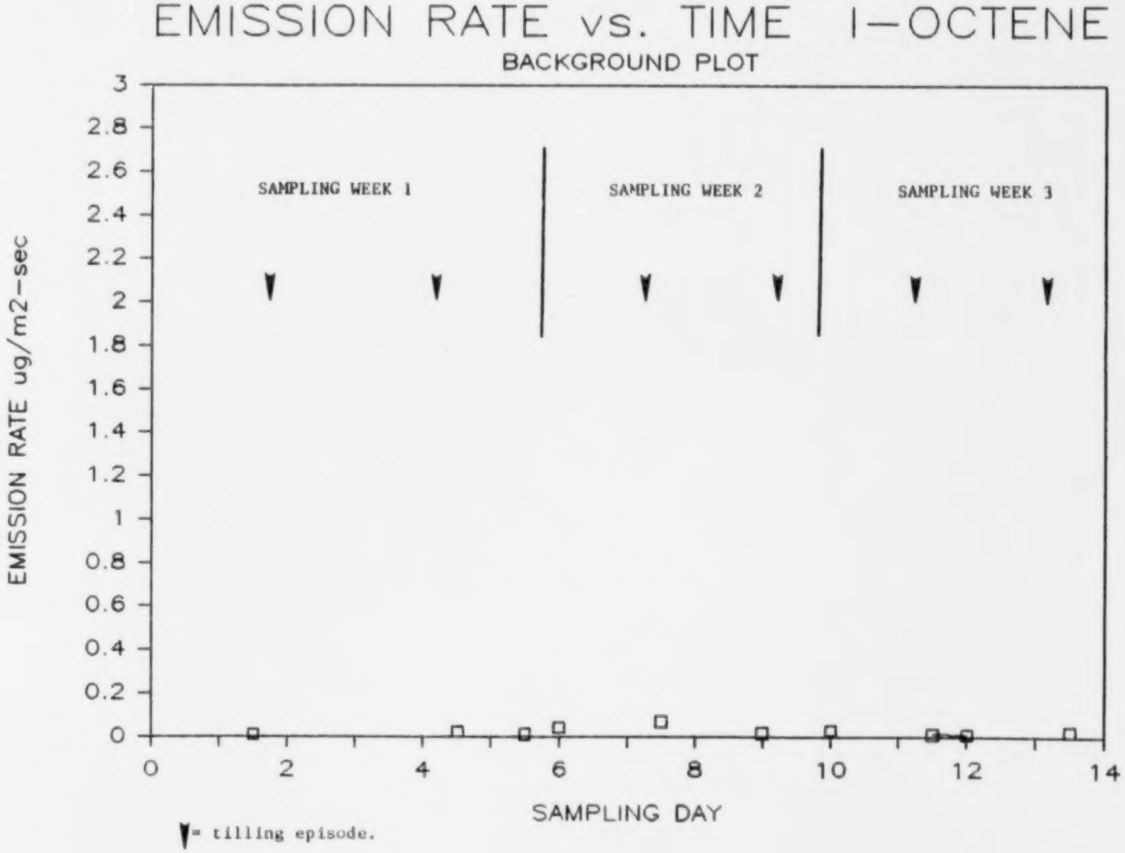


Figure 30. Emission rate vs. time for Plot B, 1-octene.

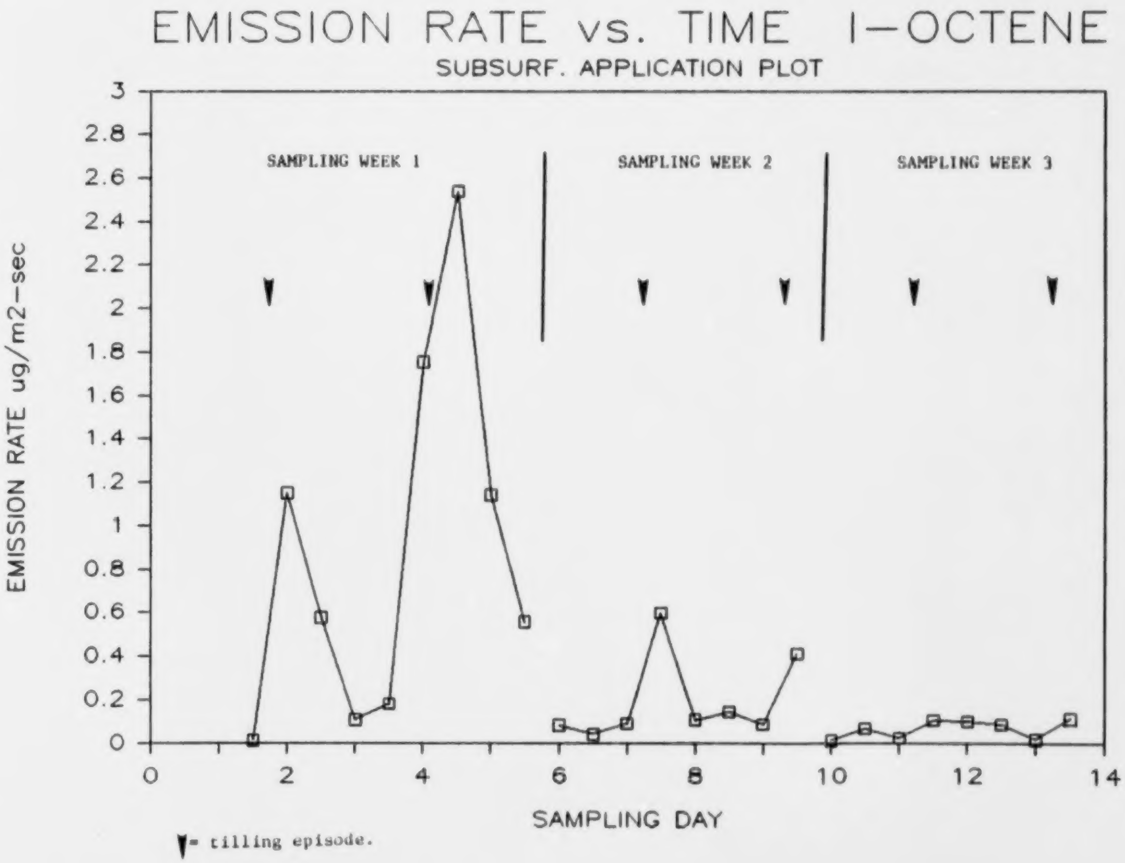


Figure 31. Emission rate vs. time for Plot C, 1-octene.

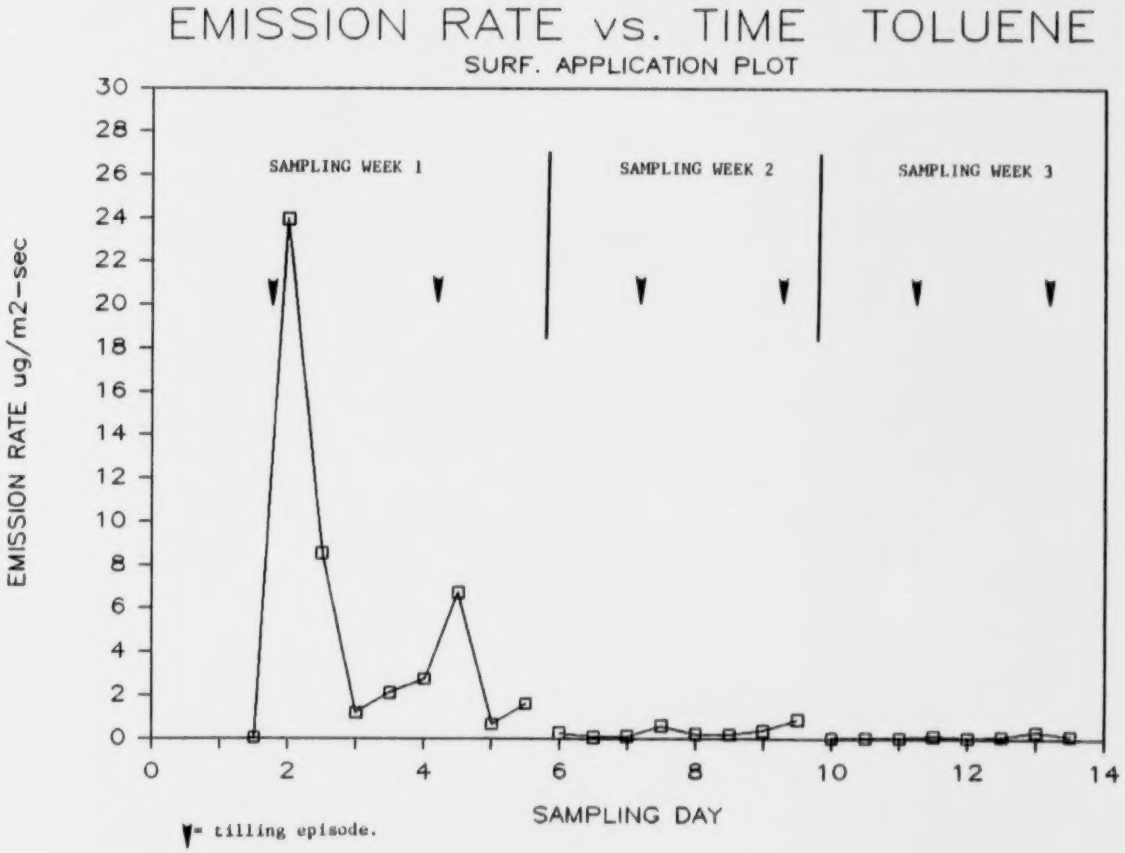


Figure 32. Emission rate vs. time for Plot A, toluene.

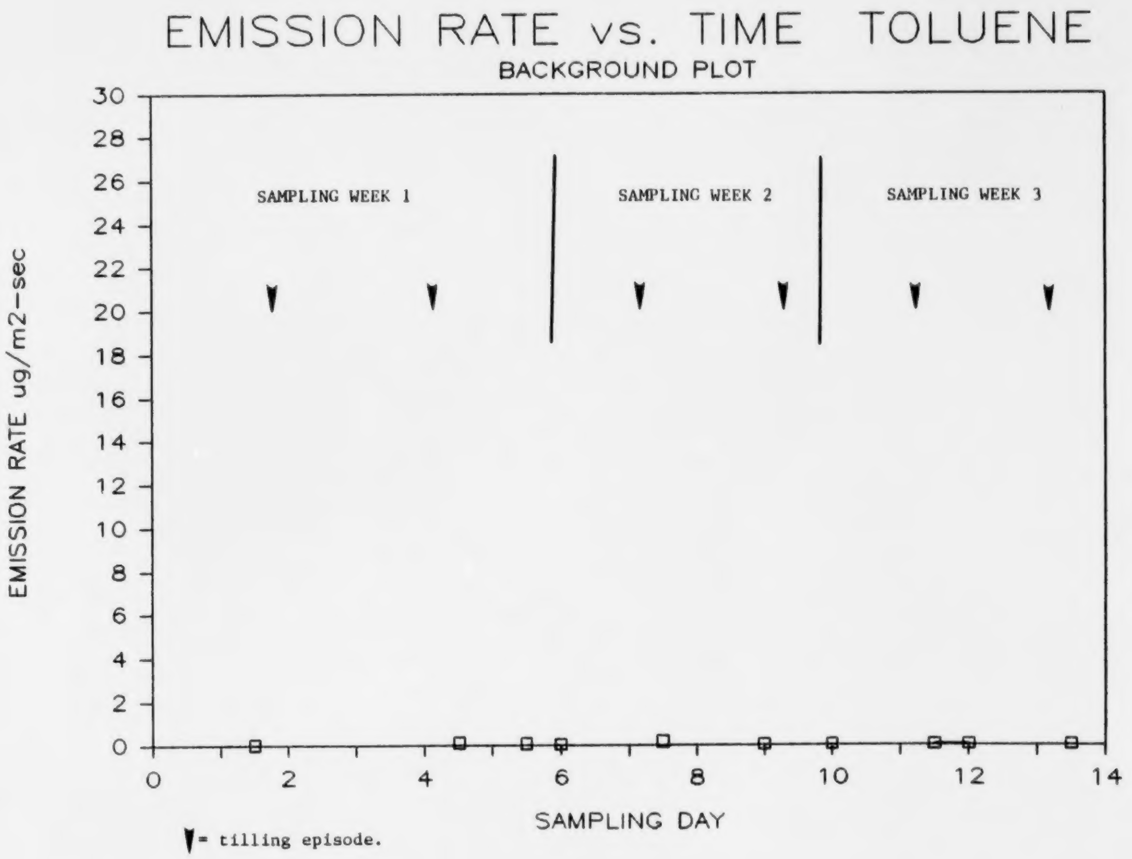


Figure 33. Emission rate vs. time for Plot B, toluene.

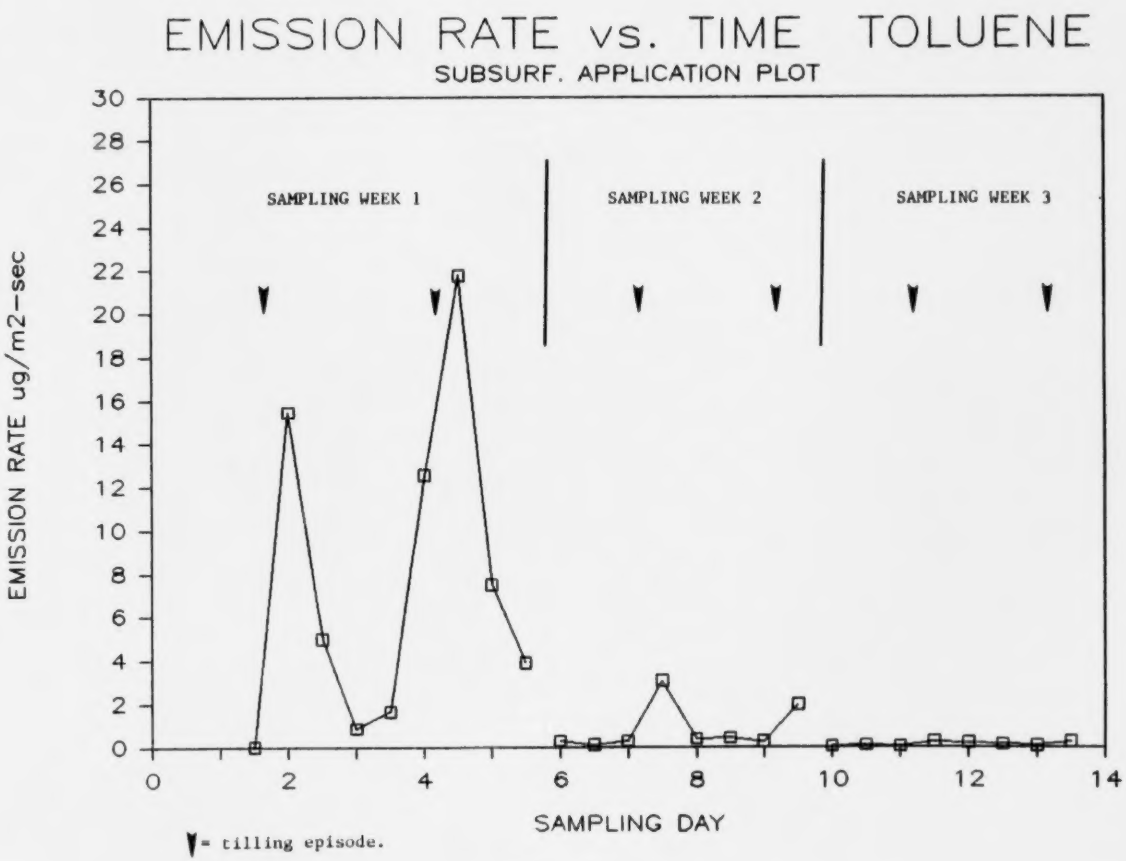


Figure 34. Emission rate vs. time for Plot C, toluene.

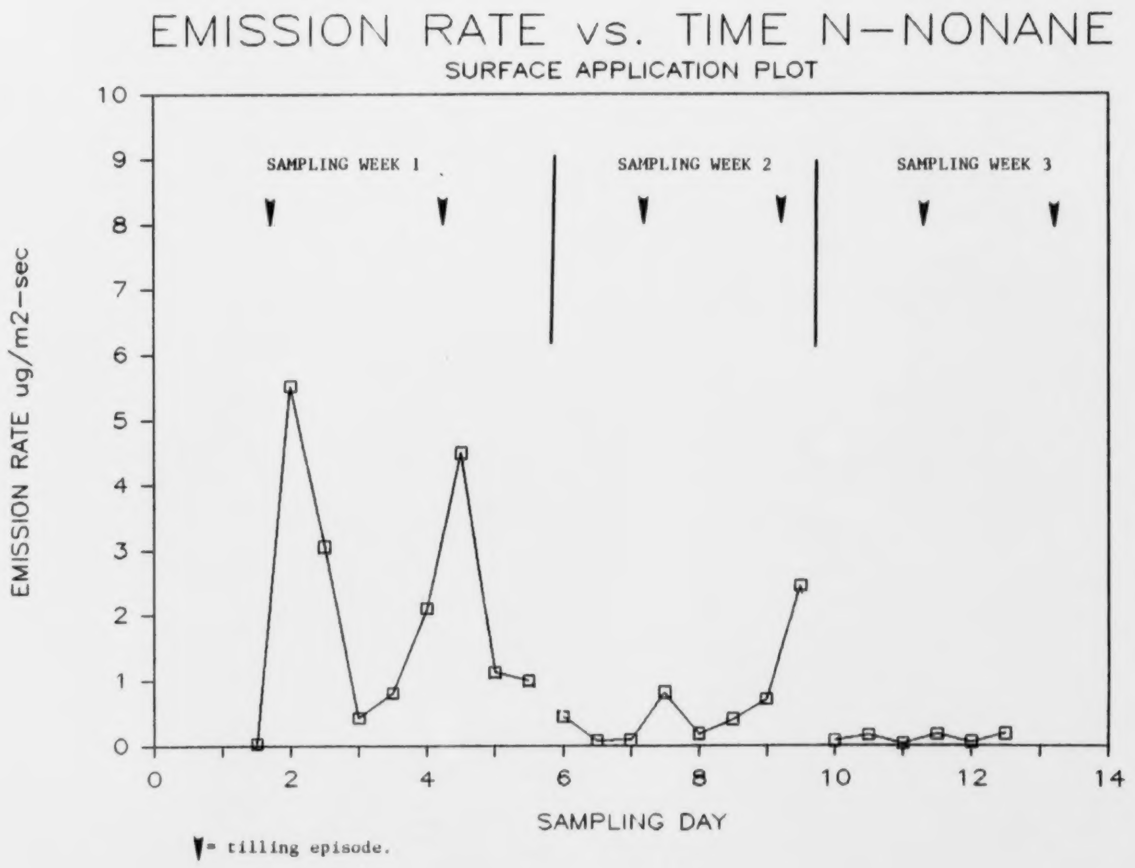


Figure 35. Emission rate vs. time for Plot A, n-nonane.

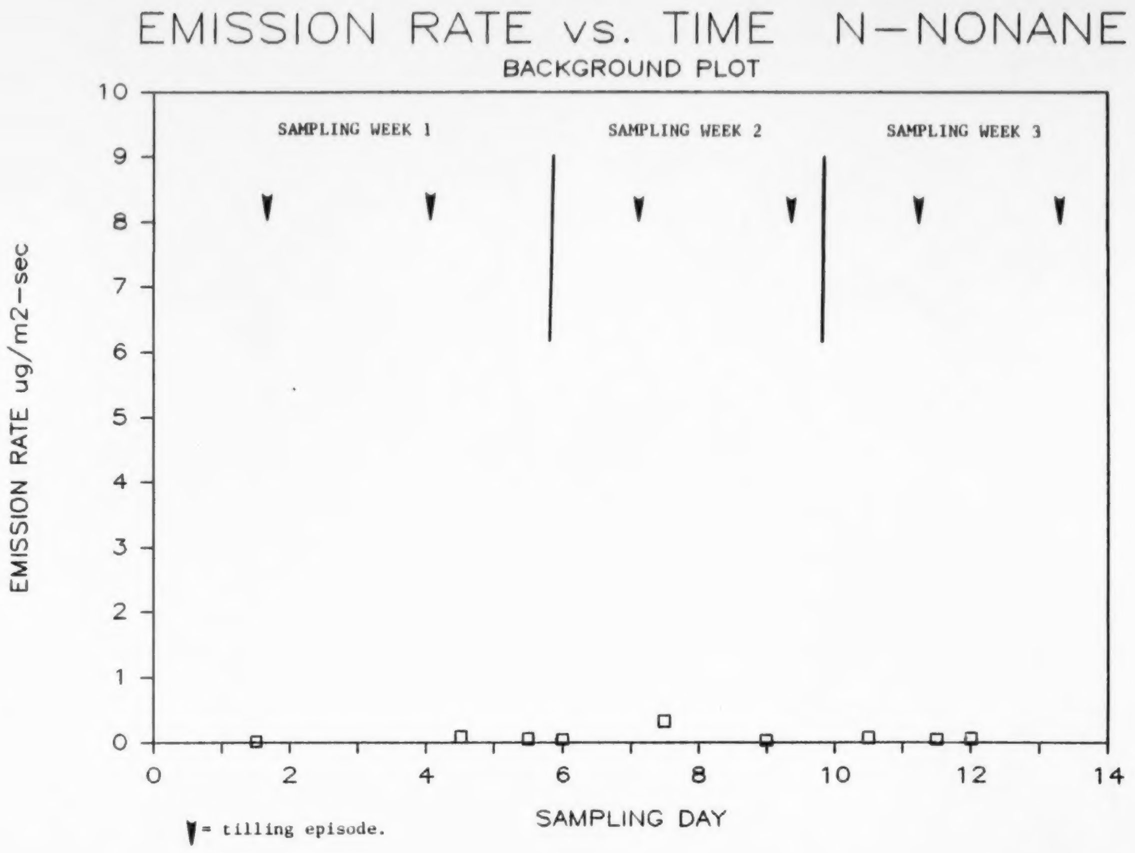


Figure 36. Emission rate vs. time for Plot B, n-nonane.

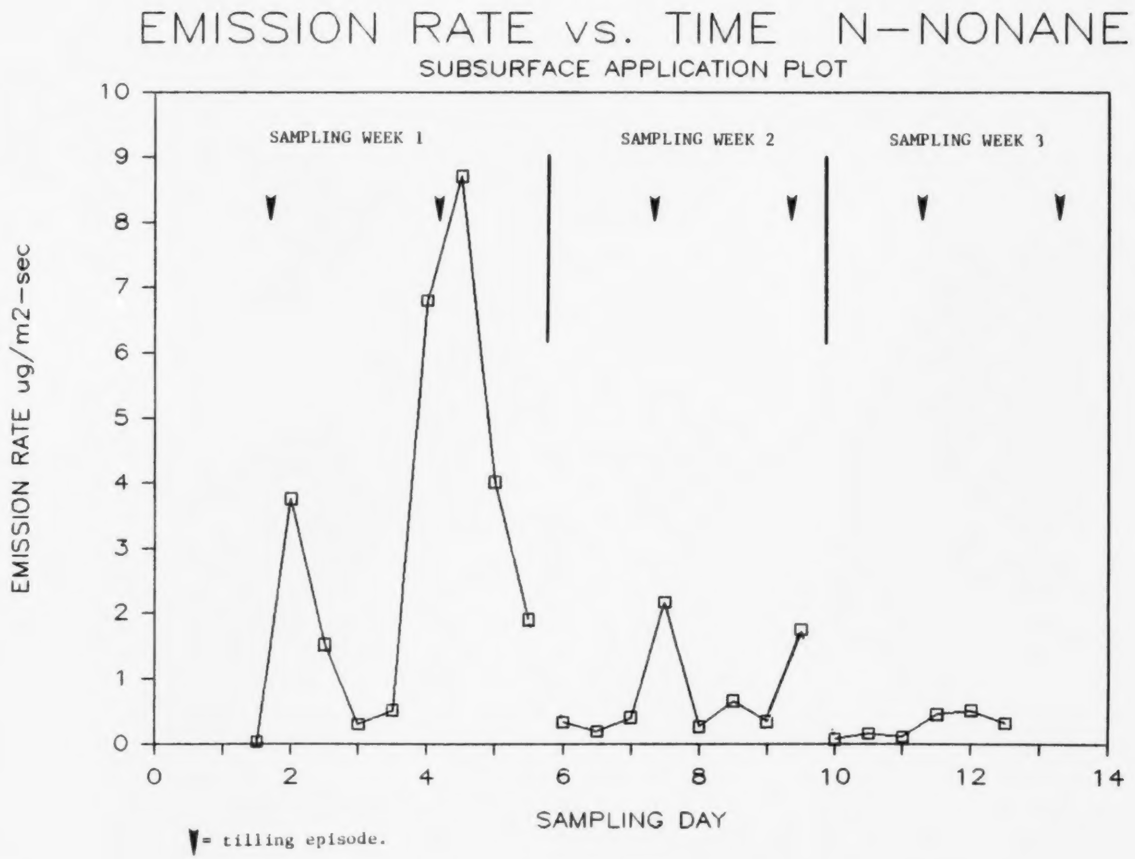


Figure 37. Emission rate vs. time for Plot C, n-nonane.

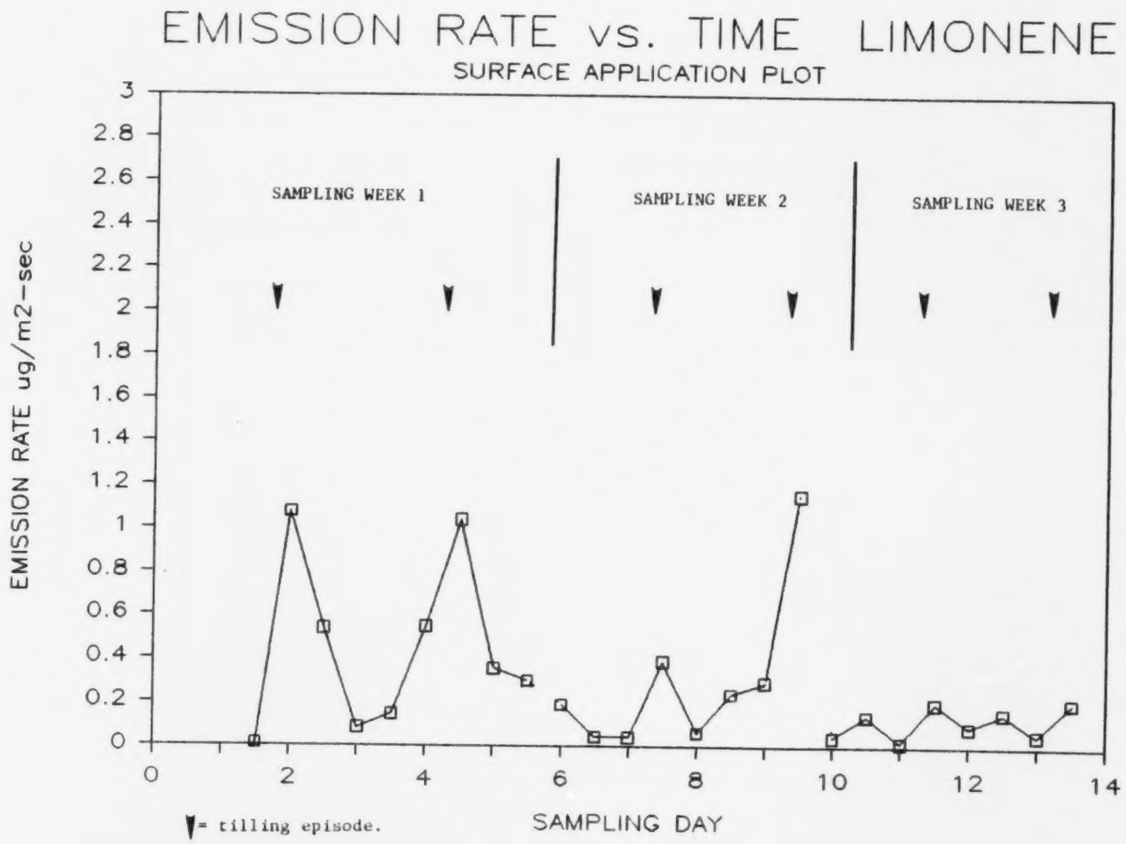


Figure 38. Emission rate vs. time for Plot A, limonene.

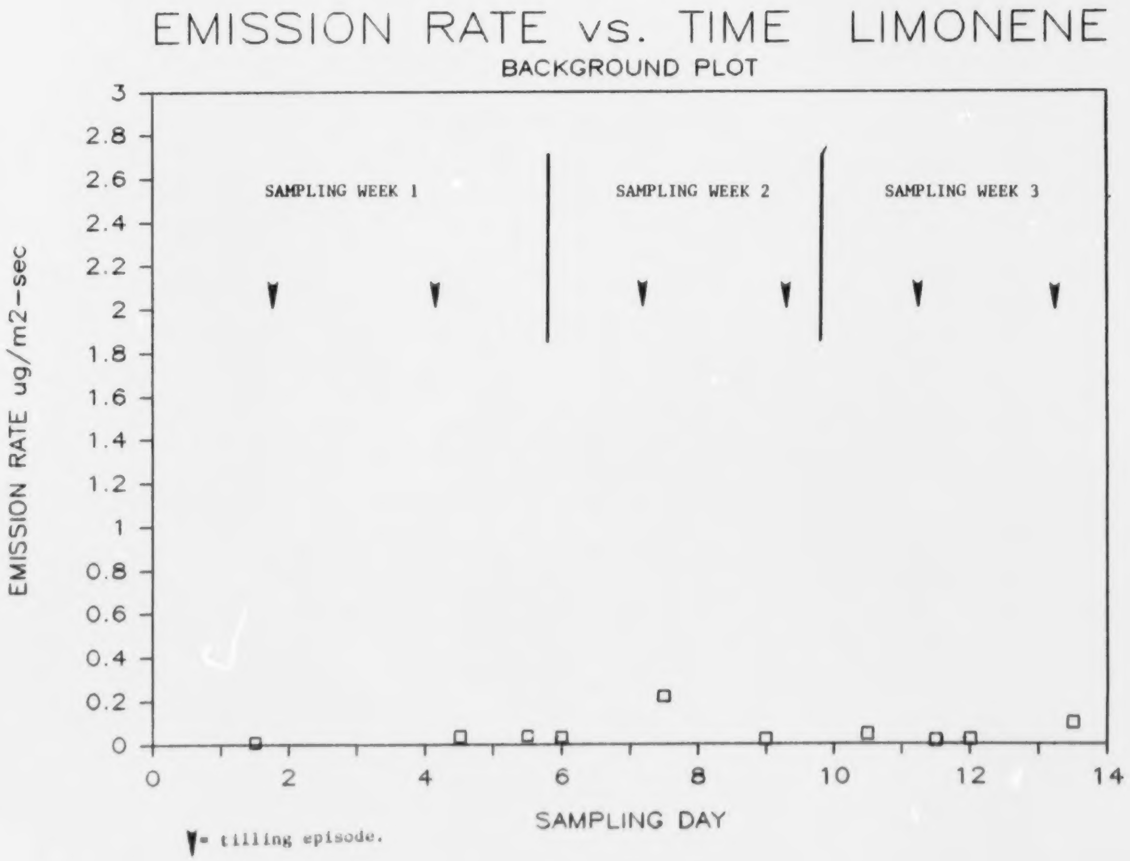


Figure 39. Emission rate vs. time for Plot B, limonene.

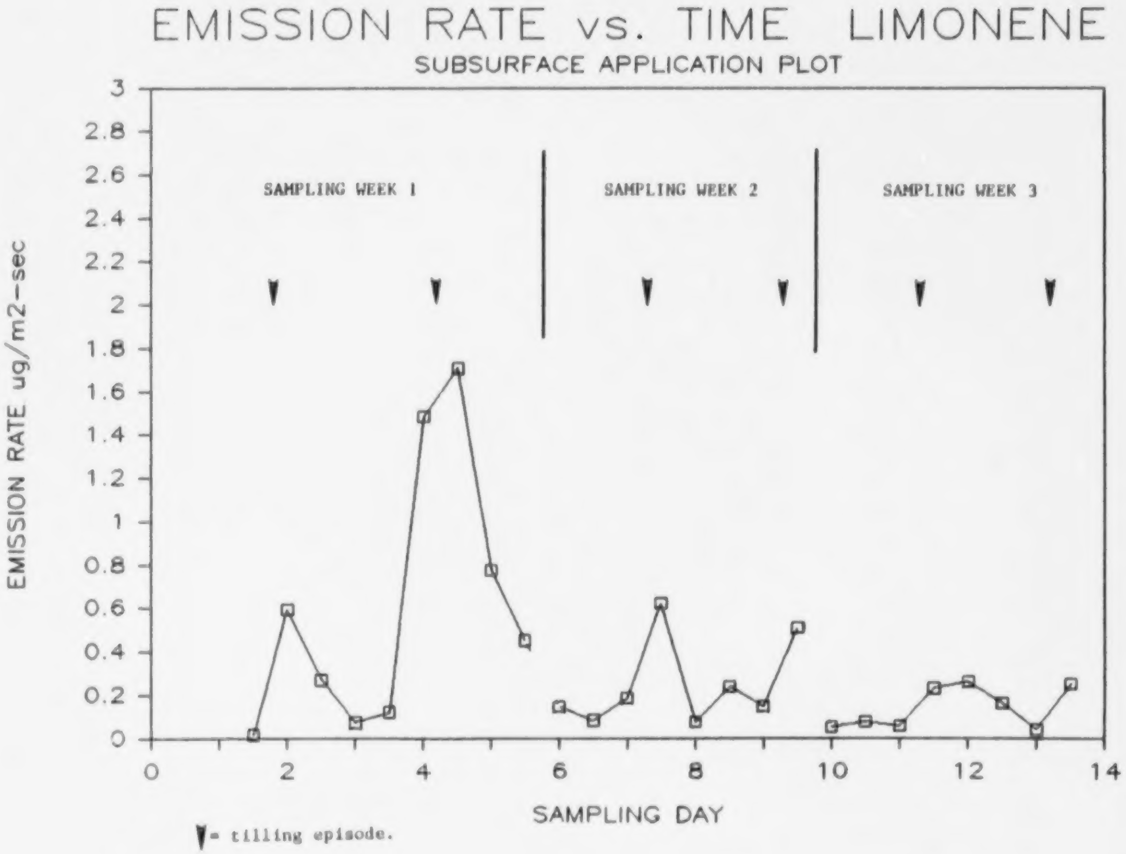


Figure 40. Emission rate vs. time for Plot C, limonene.

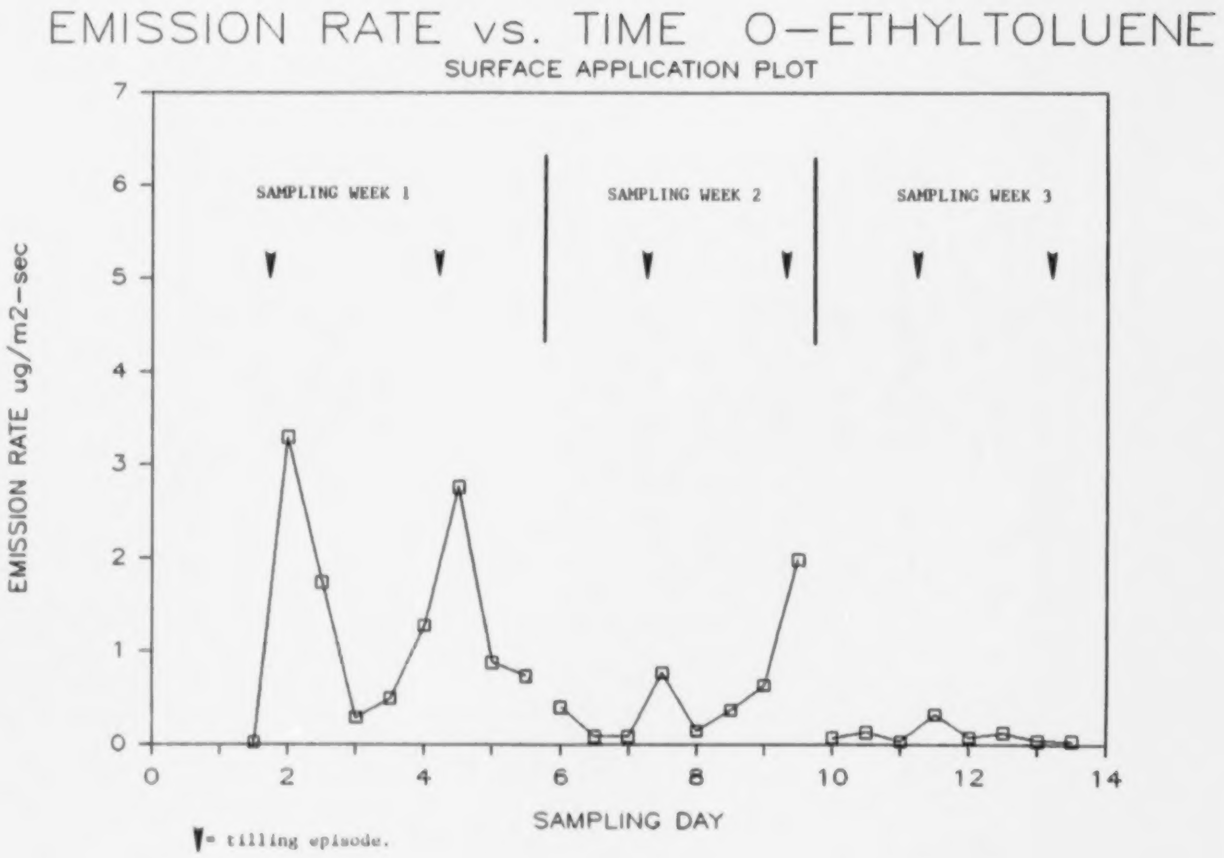


Figure 41. Emission rate vs. time for Plot A, o-ethyltoluene.

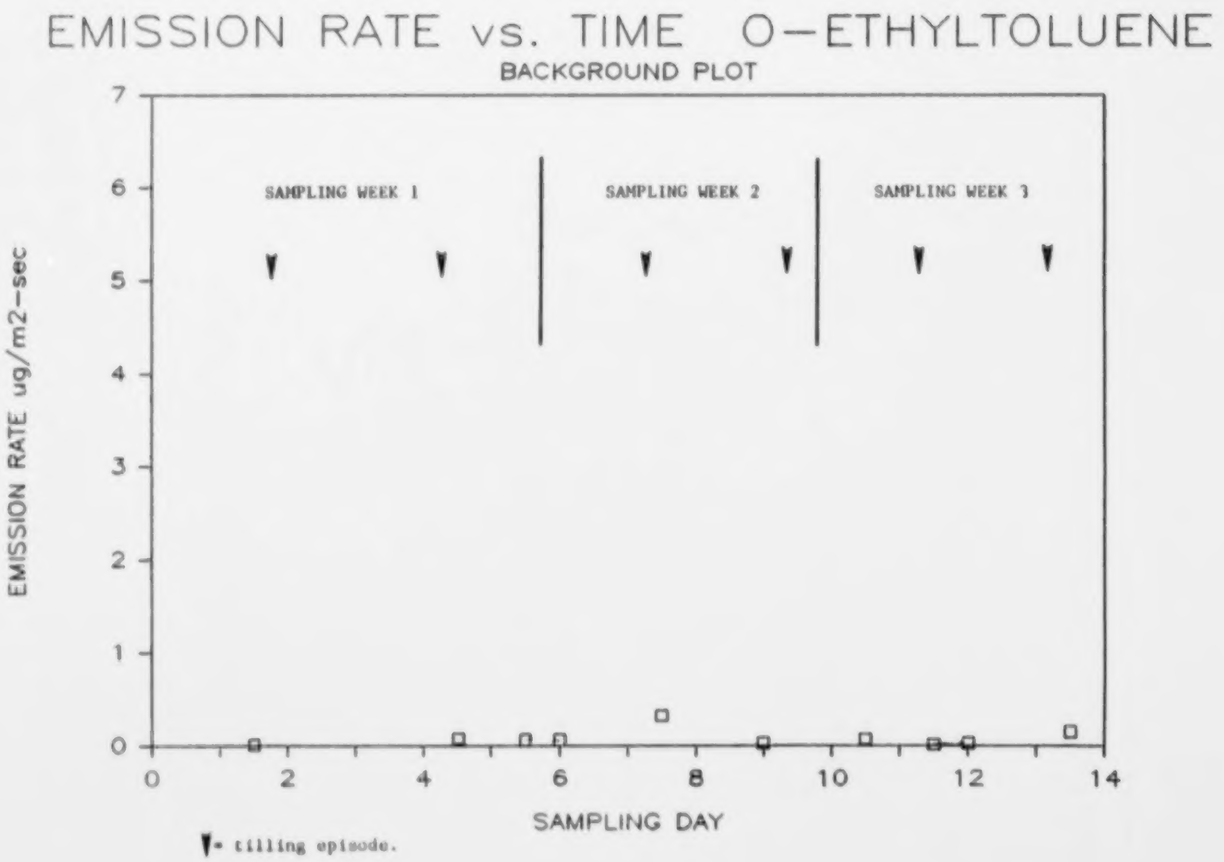


Figure 42. Emission rate vs. time for Plot B, o-ethyltoluene.

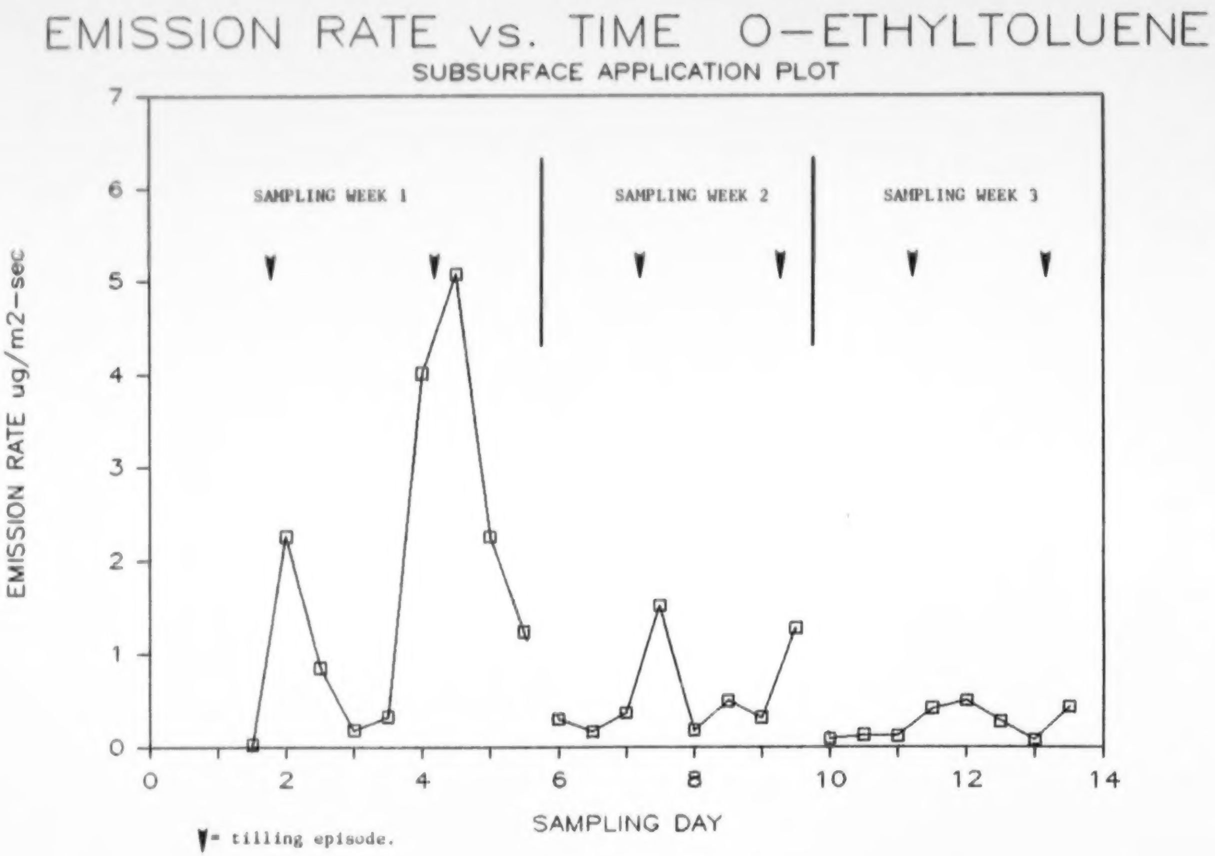


Figure 43. Emission rate vs. time for Plot C, o-ethyltoluene.

TABLE 27. AVERAGE MEASURED EMISSION RATES BY PLOT BY HALF-DAY FOR SELECTED COMPOUNDS.

Compound	Sampling Day	Date	Emission Rate (ug/m^2-s) Plot A (Surface)	Plot B (Background)	Plot C (Subsurface)
N-Heptane	0	10/09/84	0.0127	0.0051	0.0141
	1	10/10/84	8.8729		5.5803
		10/10/84	5.762		2.6937
	2	10/11/84	0.8486		0.4755
		10/11/84	1.4555		0.9027
	3	10/12/84	2.4636		8.0834
		10/12/84	4.634	0.0632	13.8526
	4	10/13/84	0.8799		5.2499
		10/13/84	1.1131	0.0194	2.3691
	5	10/23/84	0.2048	0.006	0.2359
		10/23/84	0.0391		0.0812
	6	10/24/84	0.0511		0.2651
		10/24/84	0.5018	0.0587	2.63
	7	10/25/84	0.1615		0.3781
		10/25/84	0.1433		0.3965
	8	10/26/84	0.3159	0.0112	0.2179
		10/26/84	0.8636		1.4562
	9	11/08/84	0.0096		0.0165
		11/08/84	0.0332	0.0082	0.0622
	10	11/09/84	0.0066		0.0317
		11/09/84	0.067	0.0055	0.188
	11	11/10/84	0.0088	0.0064	0.1707
		11/10/84	0.0435		0.125
	12	11/12/84	0.015		0.0245
		11/12/84	0.0751	0.021	0.1856
Methyl-Cyclohexane	0	10/09/84	0.0516	0.0189	0.0405
	1	10/10/84	9.8523		6.6313
		10/10/84	5.9091		2.7601
	2	10/11/84	0.9297		0.5344
		10/11/84	1.6485		1.0862
	3	10/12/84	2.8357		8.6772
		10/12/84	5.453	0.105	13.9151
	4	10/13/84	1.1915		5.4783
		10/13/84	1.3717	0.0321	3.0476
	5	10/23/84	0.3378	0.019	0.3803
		10/23/84	0.0711		0.1386
	6	10/24/84	0.1111		0.3811
		10/24/84	0.9336	0.1242	3.2074
	7	10/25/84	0.2744		0.4859
		10/25/84	0.3615		0.605
	8	10/26/84	0.5443	0.0204	0.3538
		10/26/84	1.6346		1.8688
	9	11/08/84	0.016		0.0328
		11/08/84	0.0884	0.0179	0.0976
	10	11/09/84	0.0146		0.0582
		11/09/84	0.2744	0.0146	0.3464
	11	11/10/84	0.0383	0.0077	0.3114
		11/10/84	0.1335		0.2668
	12	11/12/84	0.0329		0.0556
		11/12/84	0.321	0.0571	0.3873

(Continued)

TABLE 27. (Continued)

Compound	Sampling Day	Date	Emission Rate (ug/m^2-s)		
			Plot A (Surface)	Plot B (Background)	Plot C (Subsurface)
3-Methyl Heptane	0	10/09/84	0.0367	0.0182	0.0405
	1	10/10/84	6.5896		4.8763
		10/10/84	4.6747		2.2174
	2	10/11/84	0.7015		0.4486
		10/11/84	1.2818		0.8274
	3	10/12/84	2.6941		8.0661
		10/12/84	5.6325	0.1095	12.2626
	4	10/13/84	1.2124		6.4295
		10/13/84	1.2642	0.0401	2.5934
	5	10/23/84	0.4067	0.0255	0.375
		10/23/84	0.0743		0.1395
	6	10/24/84	0.1026		0.3825
		10/24/84	0.978	0.1931	2.8789
	7	10/25/84	0.255		0.3911
		10/25/84	0.4089		0.6193
	8	10/26/84	0.696	0.0428	0.3831
		10/26/84	2.0088		1.9189
	9	11/08/84	0.0255		0.0424
		11/08/84	0.1123	0.0296	0.1174
	10	11/09/84	0.0169		0.0713
		11/09/84	0.3549	0.0329	0.4095
	11	11/10/84	0.0536	0.0154	0.3795
		11/10/84	0.1833		0.2921
	12	11/12/84	0.0287		0.0623
		11/12/84	0.3821	0.0829	0.4586
N-Nonane	0	10/09/84	0.0203	0.0085	0.0238
	1	10/10/84	5.5244		3.7605
		10/10/84	3.051		1.5177
	2	10/11/84	0.4295		0.2994
		10/11/84	0.8117		0.509
	3	10/12/84	2.0996		6.7962
		10/12/84	4.4927	0.0846	8.7118
	4	10/13/84	1.1246		4.0105
		10/13/84	0.9995	0.0513	1.9002
	5	10/23/84	0.4393	0.0378	0.3329
		10/23/84	0.0727		0.1828
	6	10/24/84	0.0844		0.4007
		10/24/84	0.815	0.3221	2.1665
	7	10/25/84	0.1766		0.2586
		10/25/84	0.3996		0.6501
	8	10/26/84	0.7134	0.0241	0.3367
		10/26/84	2.4575		1.7469
	9	11/08/84	0.0663		0.0652
		11/08/84	0.153	0.0659	0.1532
	10	11/09/84	0.0217		0.1086
		11/09/84	0.1713	0.0397	0.4505
	11	11/10/84	0.0476	0.0494	0.5127
		11/10/84	0.1824		0.3091
	12	11/12/84	0.0326		0.0595
		11/12/84	0.1659	0.1127	0.4337

(Continued)

TABLE 27. (Continued)

Compound	Sampling Day	Date	Emission Rate (ug/m^2-s)		
			Plot A (Surface)	Plot B (Background)	Plot C (Subsurface)
1-Methyl Cyclohexene	0	10/09/84	0.0096	0.0024	0.0112
	1	10/10/84	0.7436		1.218
		10/10/84	1.2185		0.6088
	2	10/11/84	0.2216		0.0828
		10/11/84	0.1783		0.213
	3	10/12/84	0.6435		2.0353
		10/12/84	1.0773	0.0356	3.0855
	4	10/13/84	0.2621		1.269
		10/13/84	0.2953	0.0106	0.6784
	5	10/23/84	0.0931	0.008	0.0788
		10/23/84	0.0169		0.0339
	6	10/24/84	0.0246		0.0917
		10/24/84	0.216	0.0491	
	7	10/25/84	0.0514		0.095
		10/25/84	0.0888		0.1406
	8	10/26/84	0.1209	0.009	0.0989
		10/26/84	0.5116		0.4426
	9	11/08/84	0.0175		0.0091
		11/08/84	0.0255	0.0074	0.0238
	10	11/09/84	0.0045		0.0173
		11/09/84	0.0723	0.0087	0.0747
	11	11/10/84	0.0119	0.0029	0.0749
		11/10/84	0.0376		0.0579
	12	11/12/84	0.0091		0.0147
		11/12/84	0.0709	0.0191	0.0964
1-Octene	0	10/09/84	0.0096	0.007	0.01
	1	10/10/84	1.597		1.0851
		10/10/84	0.9579		0.5755
	2	10/11/84	0.1421		0.1069
		10/11/84	0.2511		0.1801
	3	10/12/84	0.5482		1.7538
		10/12/84	1.1621	0.0212	2.5851
	4	10/13/84	0.2605		1.1407
		10/13/84	0.2469	0.0093	0.5423
	5	10/23/84	0.1087	0.0402	0.0817
		10/23/84	0.0162		0.0383
	6	10/24/84	0.0222		0.0873
		10/24/84	0.2302	0.0671	0.5969
	7	10/25/84	0.0562		0.1045
		10/25/84	0.1004		0.1415
	8	10/26/84	0.1584	0.016	0.0835
		10/26/84	0.5479		0.4103
	9	11/08/84	0.0134		0.0101
		11/08/84	0.0282	0.0274	0.0894
	10	11/09/84	0.004		0.0227
		11/09/84	0.091	0.0106	0.1026
	11	11/10/84	0.0154	0.0075	0.0987
		11/10/84	0.0628		0.0836
	12	11/12/84	0.0077		0.0145
		11/12/84	0.1048	0.0227	0.1068

(Continued)

TABLE 27. (Continued)

Compound	Sampling Day	Date	Emission Rate (ug/m^2-s)		
			Plot A (Surface)	Plot B (Background)	Plot C (Subsurface)
B-Pinene	0	10/09/84	0.0122	0.0119	0.0174
	1	10/10/84	1.9184		1.279
		10/10/84	1.0621		0.5158
	2	10/11/84	0.1375		0.1142
		10/11/84	0.2775		0.1973
	3	10/12/84	0.7399		2.5381
		10/12/84	1.7501	0.0544	3.0765
	4	10/13/84	0.5424		1.374
		10/13/84	0.434	0.0394	0.736
	5	10/23/84	0.2515	0.0615	0.1931
		10/23/84	0.0487		0.1166
	6	10/24/84	0.0512		0.2336
		10/24/84	0.5275	0.2508	0.9324
	7	10/25/84	0.0957		0.1217
		10/25/84	0.293		0.3124
	8	10/26/84	0.4083	0.0206	0.1939
		10/26/84	1.3385		0.7915
	9	11/08/84	0.044		0.054
		11/08/84	0.1447	0.0519	0.1005
	10	11/09/84	0.019		0.0737
		11/09/84	0.2832	0.0209	0.3041
	11	11/10/84	0.0984	0.0374	0.3337
		11/10/84	0.1885		0.2109
	12	11/12/84	0.0374		0.0465
		11/12/84	0.2777	0.1059	0.3222
Limonene	0	10/09/84	0.007	0.0066	0.0135
	1	10/10/84	1.0776		0.5929
		10/10/84	0.5363		0.2689
	2	10/11/84	0.081		0.0719
		10/11/84	0.1446		0.119
	3	10/12/84	0.5474		1.4856
		10/12/84	1.0397	0.0335	1.7081
	4	10/13/84	0.3557		0.7739
		10/13/84	0.2998	0.0376	0.4519
	5	10/23/84	0.1902	0.0315	0.146
		10/23/84	0.0404		0.0812
	6	10/24/84	0.039		0.185
		10/24/84	0.388	0.2183	0.6208
	7	10/25/84	0.0615		0.0742
		10/25/84	0.2374		0.2372
	8	10/26/84	0.2923	0.0179	0.1471
		10/26/84	1.1556		0.5081
	9	11/08/84	0.0386		0.0501
		11/08/84	0.1358	0.0433	0.0739
	10	11/09/84	0.0157		0.0551
		11/09/84	0.1977	0.0143	0.2308
	11	11/10/84	0.0884	0.0196	0.2607
		11/10/84	0.1541		0.1623
	12	11/12/84	0.0516		0.0386
		11/12/84	0.2038	0.0959	0.2531

(Continued)

TABLE 27. (Continued)

Compound	Sampling Day	Date	Emission Rate (ug/m^2-s)		
			Plot A (Surface)	Plot B (Background)	Plot C (Subsurface)
Toluene	0	10/09/84	0.0225	0.0028	
	1	10/10/84	23.9847		14.8095
		10/10/84	8.8515		4.9822
	2	10/11/84	1.1568		0.8368
		10/11/84	2.1214		1.6754
	3	10/12/84	2.7662		12.5455
		10/12/84	6.7296	0.0992	21.9384
	4	10/13/84	0.767		7.4821
		10/13/84	1.6027	0.0584	3.8297
	5	10/23/84	0.2428	0.0186	0.2668
		10/23/84	0.0567		0.0854
	6	10/24/84	0.0779		0.2755
		10/24/84	0.5723	0.1272	3.0731
	7	10/25/84	0.1777		0.3602
		10/25/84	0.1642		0.4089
	8	10/26/84	0.3301	0.0356	0.2335
		10/26/84	0.8756		1.9541
	9	11/08/84	0.0173		0.0252
		11/08/84	0.038	0.0118	0.0661
	10	11/09/84	0.016		0.0384
		11/09/84	0.0949	0.0147	0.2328
	11	11/10/84	0.0349	0.0123	0.1868
		11/10/84	0.0617		0.1142
	12	11/12/84	0.03		0.0477
		11/12/84	0.1135	0.0316	0.2283
p-, m-Xylene	0	10/09/84	0.0238	0.0053	
	1	10/10/84	15.2425		9.6056
		10/10/84	5.7499		2.8536
	2	10/11/84	0.7782		0.5955
		10/11/84	1.588		1.1279
	3	10/12/84	3.2518		10.967
		10/12/84	6.5949	0.0917	14.7919
	4	10/13/84	1.3692		6.3865
		10/13/84	1.6286	0.0865	2.7341
	5	10/23/84	0.5236	0.0329	0.4007
		10/23/84	0.0872		0.1569
	6	10/24/84	0.0914		0.4426
		10/24/84	0.7568	0.2096	2.8914
	7	10/25/84	0.201		0.3278
		10/25/84	0.2809		0.5958
	8	10/26/84	0.5695	0.033	0.3941
		10/26/84	1.5675		2.4141
	9	11/08/84	0.1479		0.0554
		11/08/84	0.0938	0.0292	0.1188
	10	11/09/84	0.025		0.0725
		11/09/84	0.1984	0.0265	0.3986
	11	11/10/84	0.0548	0.0264	0.3819
		11/10/84	0.0975		0.2007
	12	11/12/84	0.0604		0.0718
		11/12/84	0.2042	0.0687	0.3693

(Continued)

TABLE 27. (Continued)

Compound	Sampling Day	Date	Emission Rate (ug/m^2-s)		
			Plot A (Surface)	Plot B (Background)	Plot C (Subsurface)
1,3,5-Tri-Methylbenzene	0	10/09/84		0.0098	0.025
	1	10/10/84	3.1238		2.0856
		10/10/84	1.3811		0.8192
	2	10/11/84	0.2187		0.1693
		10/11/84	0.411		0.2929
	3	10/12/84	1.0496		3.2749
		10/12/84	2.2364	0.06	3.9013
	4	10/13/84	0.548		1.9655
		10/13/84		0.0491	0.9645
	5	10/23/84	0.3224	0.0568	0.2419
		10/23/84	0.0625		0.2144
	6	10/24/84	0.0654		0.2835
		10/24/84	0.6274	0.2744	1.1785
	7	10/25/84	0.12		0.1609
		10/25/84	0.3342		0.3882
	8	10/26/84	0.4905	0.0305	0.2516
		10/26/84	1.6404		0.3707
	9	11/08/84	0.0463		0.0674
		11/08/84	0.1628	0.0723	0.1349
	10	11/09/84	0.0234		0.0863
		11/09/84	0.3354	0.0319	0.3659
	11	11/10/84	0.1098	0.0301	0.4075
		11/10/84	0.2299		0.2628
	12	11/12/84	0.0405		0.0607
		11/12/84	0.3268	0.1175	0.4024
o-ethyltoluene	0	10/09/84	0.0156	0.0066	0.0212
	1	10/10/84	3.298		2.2623
		10/10/84	1.736		0.8494
	2	10/11/84	0.2881		0.1776
		10/11/84	0.4921		0.3219
	3	10/12/84	1.2719		4.0183
		10/12/84	2.763	0.0765	5.0867
	4	10/13/84	0.8726		2.2553
		10/13/84	0.7294	0.06	1.2306
	5	10/23/84	0.3926	0.054	0.2968
		10/23/84	0.0786		0.1607
	6	10/24/84	0.0803		0.3666
		10/24/84	0.7653	0.3175	1.5196
	7	10/25/84	0.1363		0.1781
		10/25/84	0.3651		0.4944
	8	10/26/84	0.6319	0.0255	0.3114
		10/26/84	1.9829		1.2764
	9	11/08/84	0.0677		0.0835
		11/08/84	0.1269	0.0628	0.1207
	10	11/09/84	0.027		0.114
		11/09/84	0.3168	0.0059	0.414
	11	11/10/84	0.0733	0.0225	0.5007
		11/10/84	0.1231		0.2719
	12	11/12/84	0.0359		0.0719
		11/12/84	0.0298	0.1453	0.4321

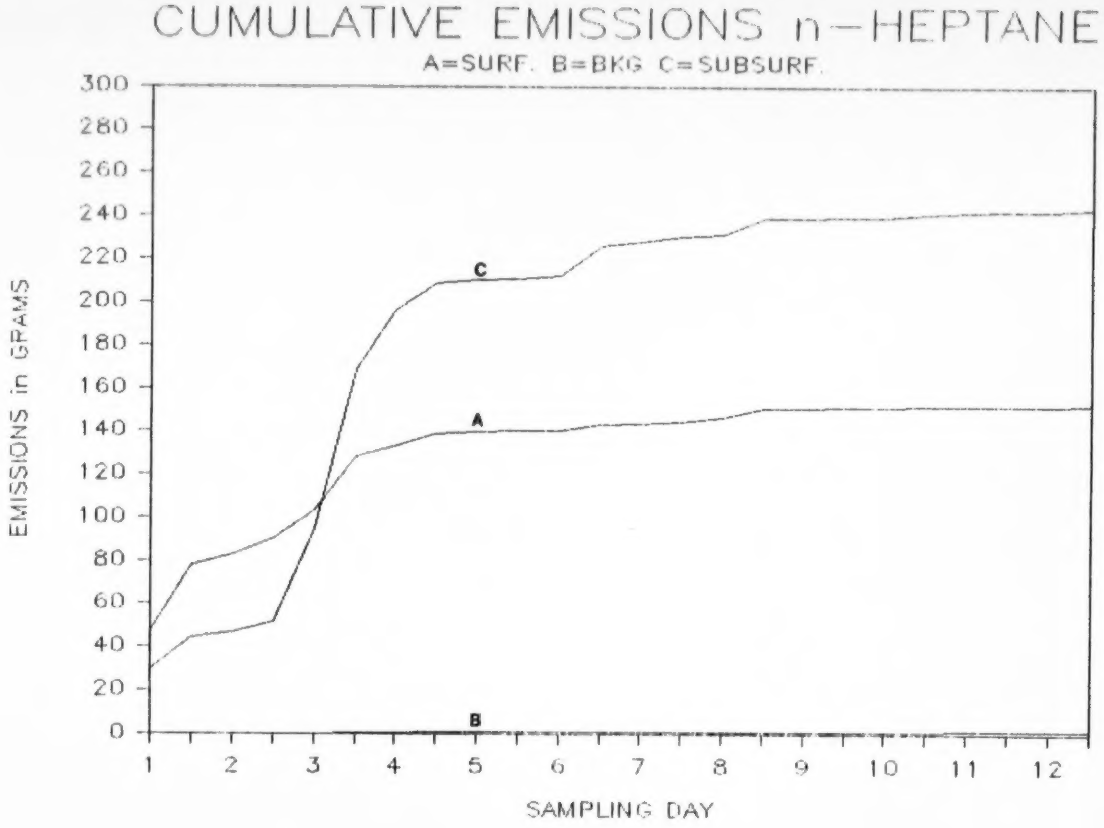


Figure 44. Cumulative measured emissions for n-heptane (only days on which sampling was done are shown).

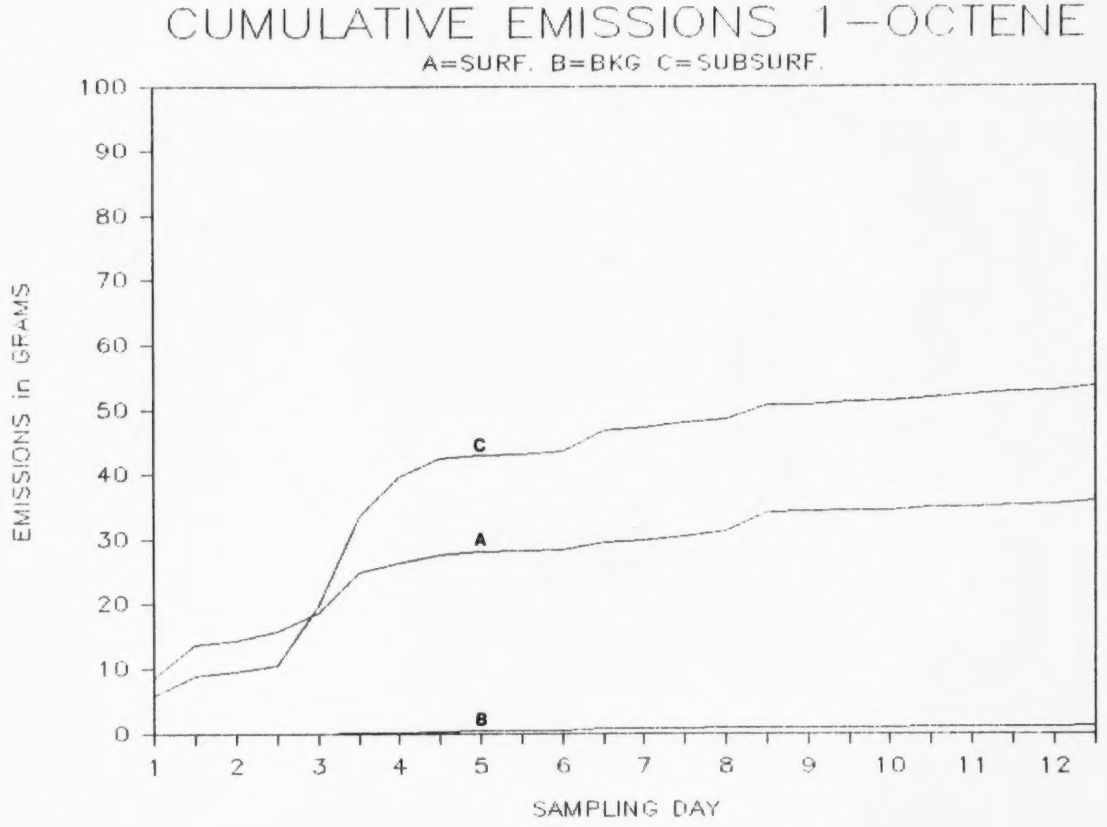


Figure 45. Cumulative measured emissions for 1-octene (only days on which sampling was done are shown).

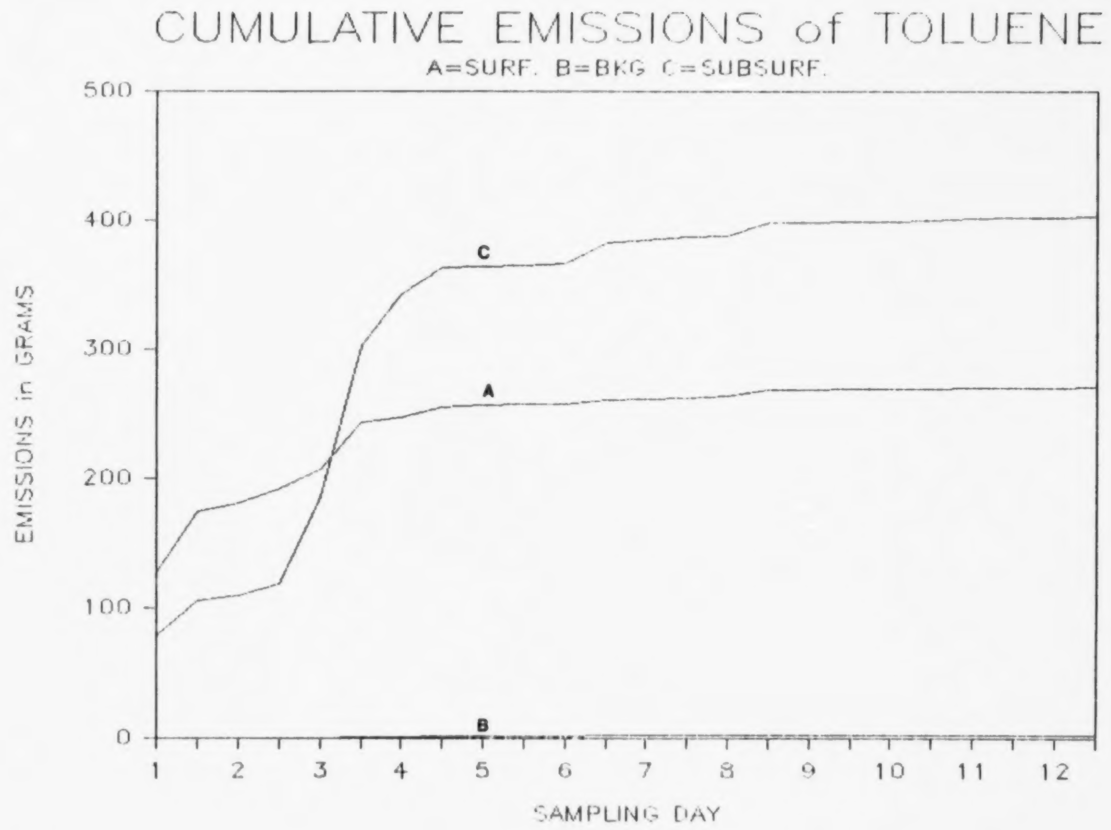


Figure 46. Cumulative measured emissions for toluene (only days on which sampling was done are shown).

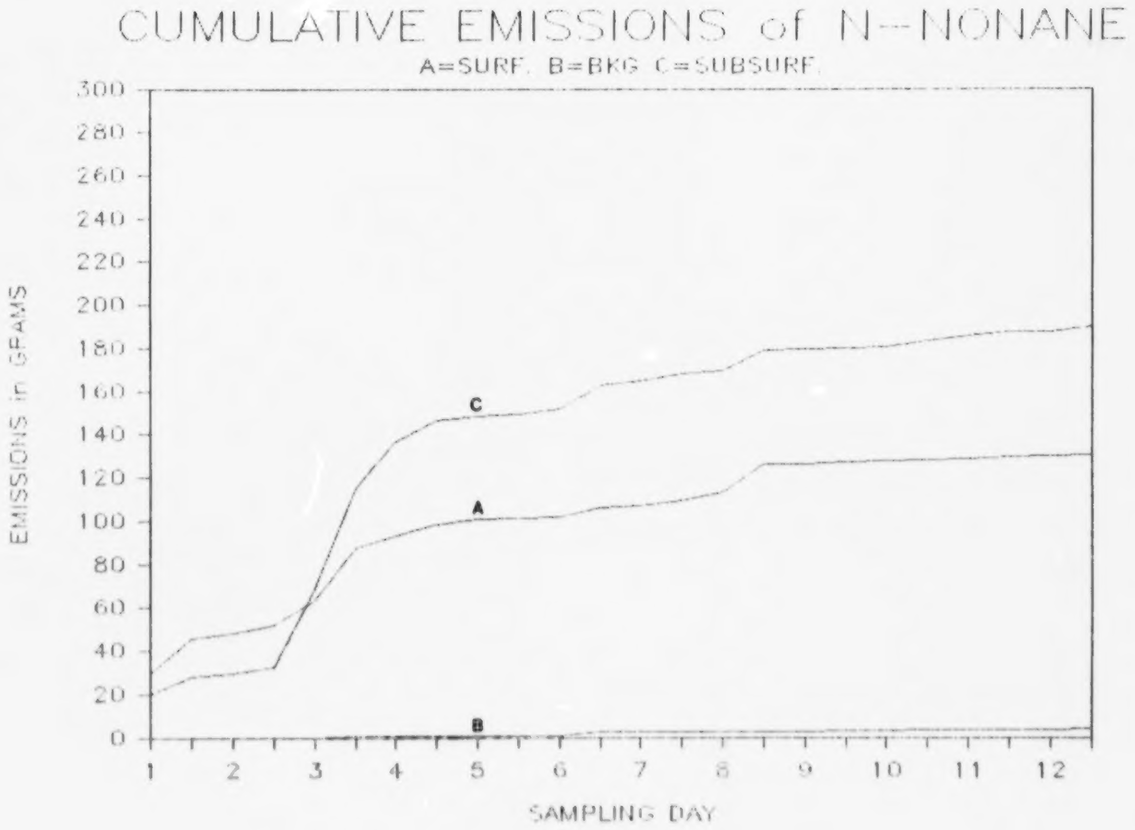


Figure 47. Cumulative measured emissions for n-nonane (only days on which sampling was done are shown).

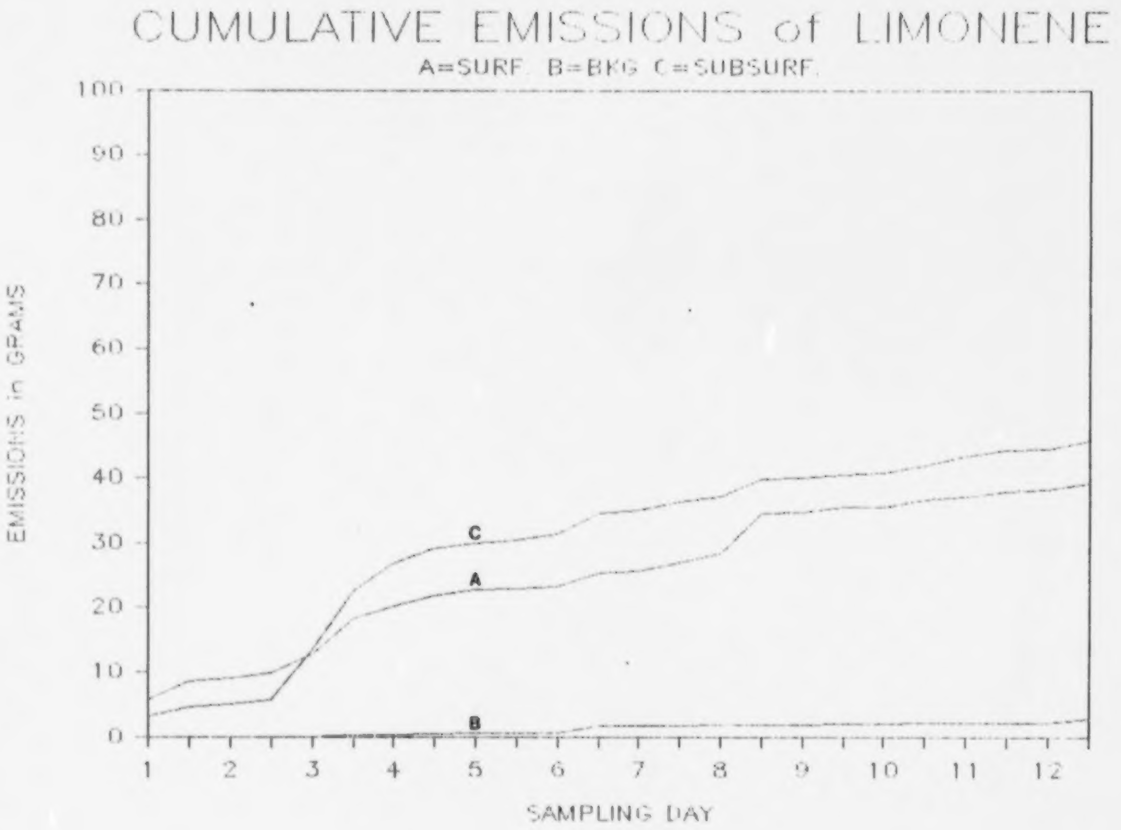


Figure 48. Cumulative measured emissions for limonene (only days on which sampling was done are shown).

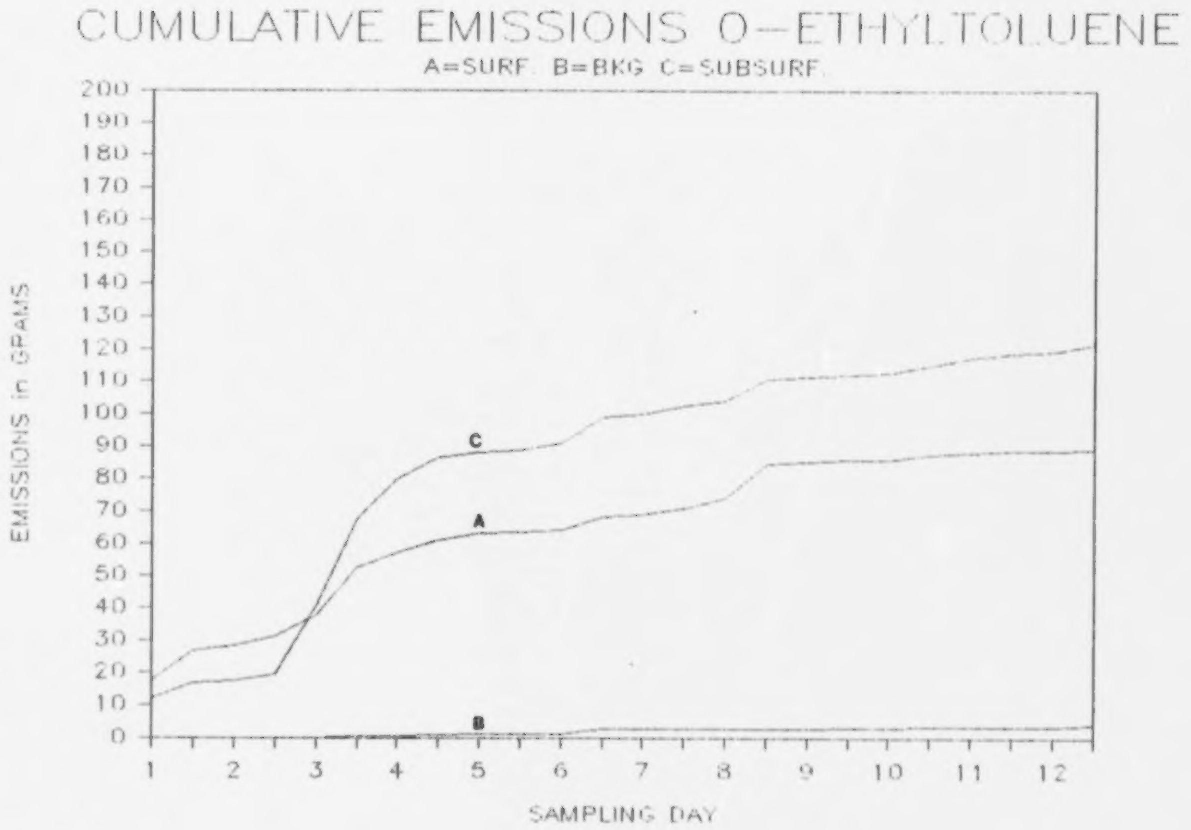


Figure 49. Cumulative measured emissions for o-ethyltoluene (only days on which sampling was done are shown).

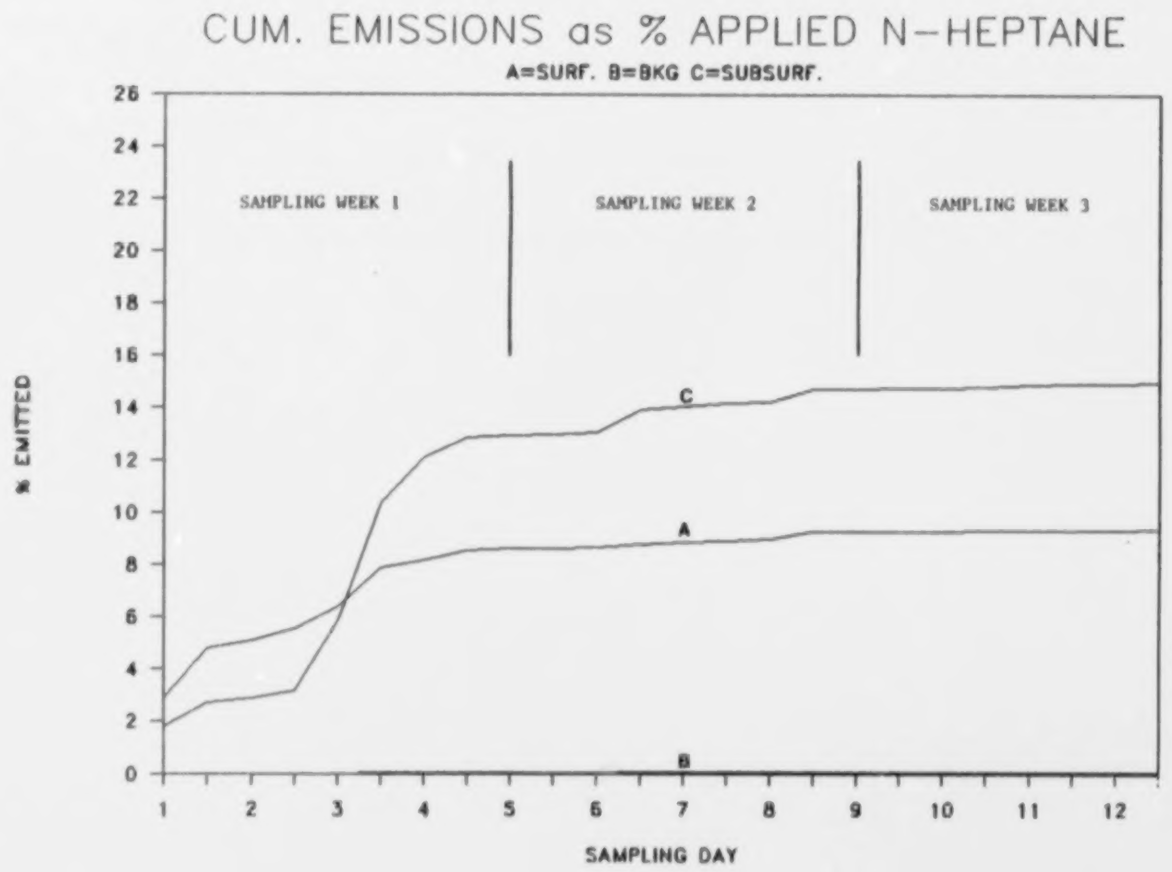


Figure 50. Cumulative measured emissions as the % of applied material, n-heptane (only days on which sampling was done are shown).

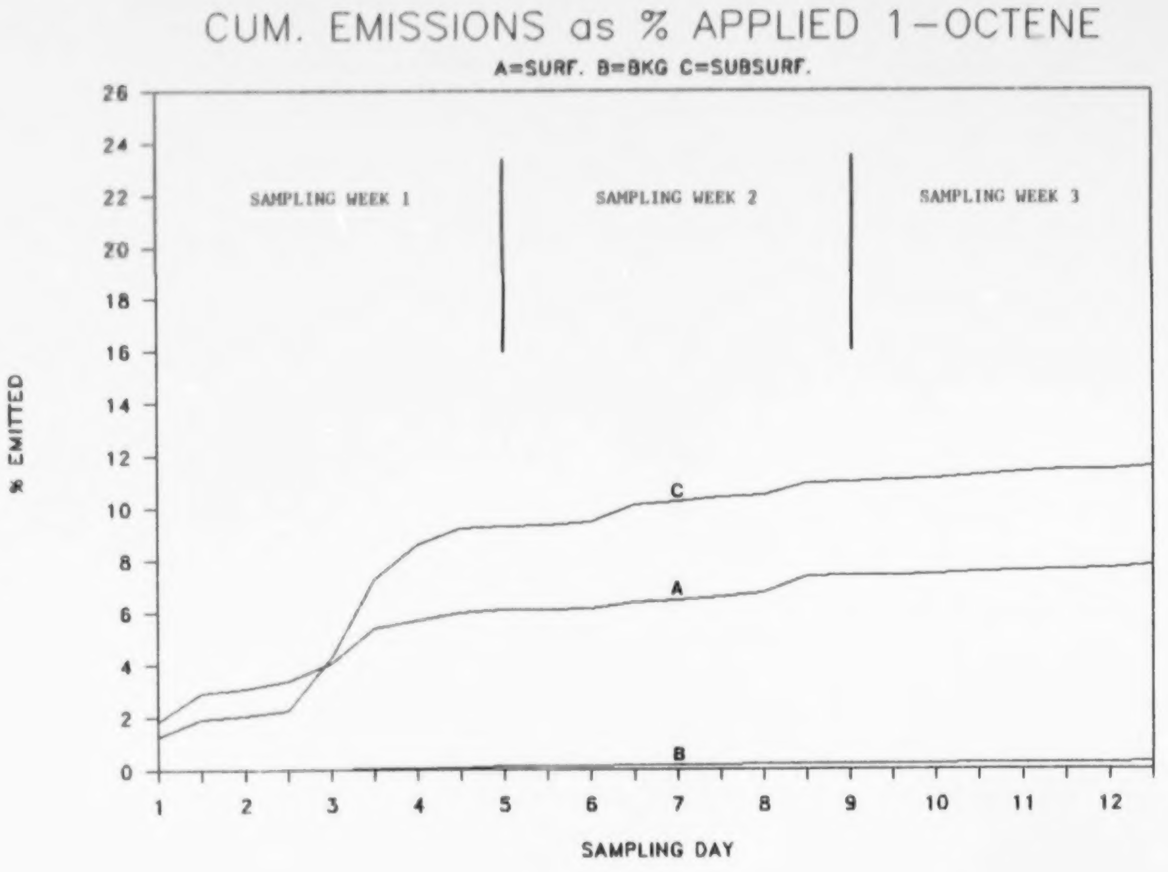


Figure 51. Cumulative measured emissions as the % of applied material, 1-octene (only days on which sampling was done are shown).

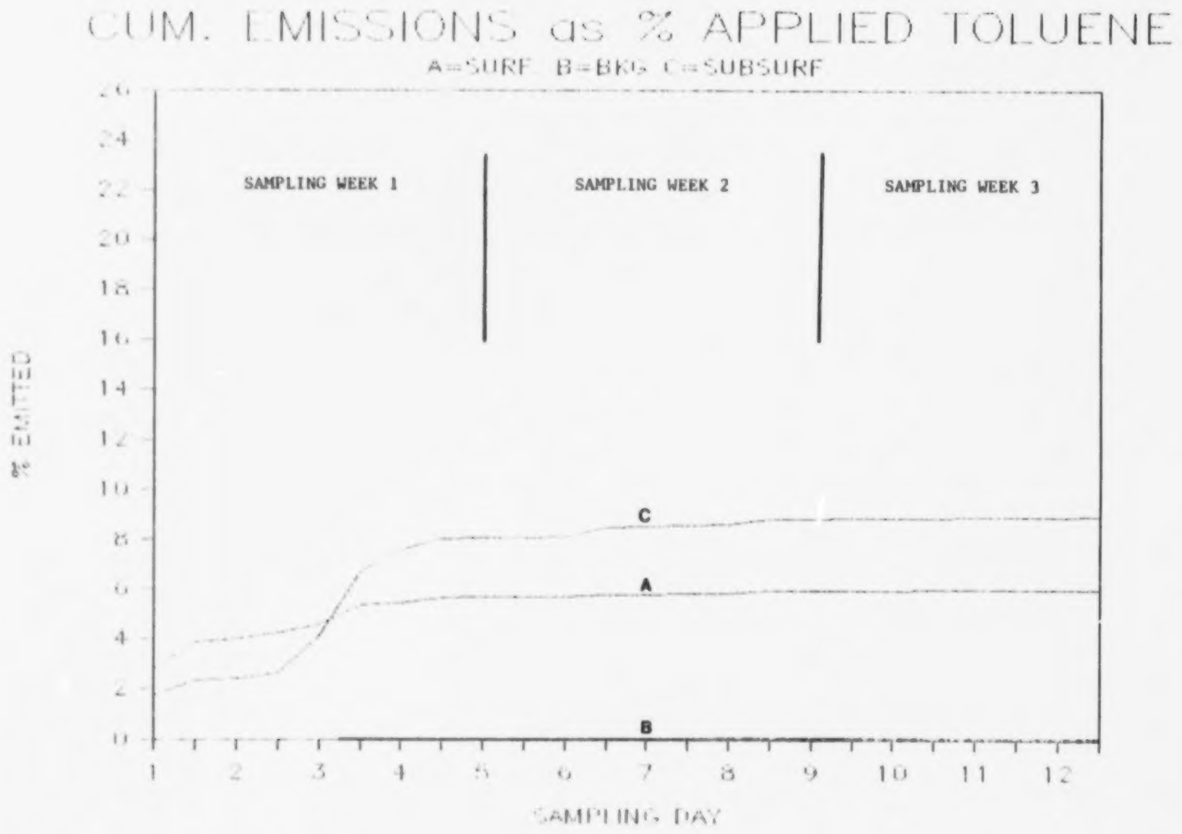


Figure 52. Cumulative measured emissions as the % of applied material, toluene (only days on which sampling was done are shown).

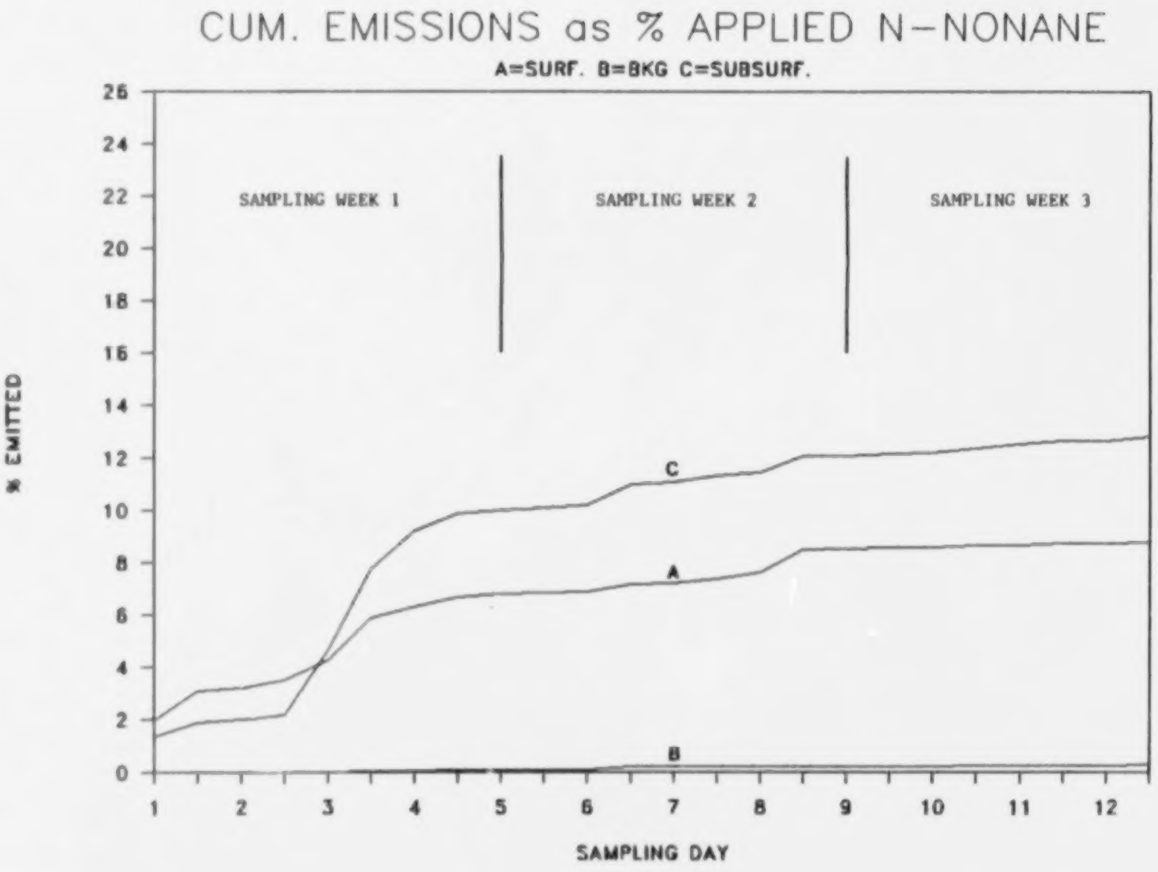


Figure 53. Cumulative measured emissions as the % of applied n-nonane (only days on which sampling was done are shown).

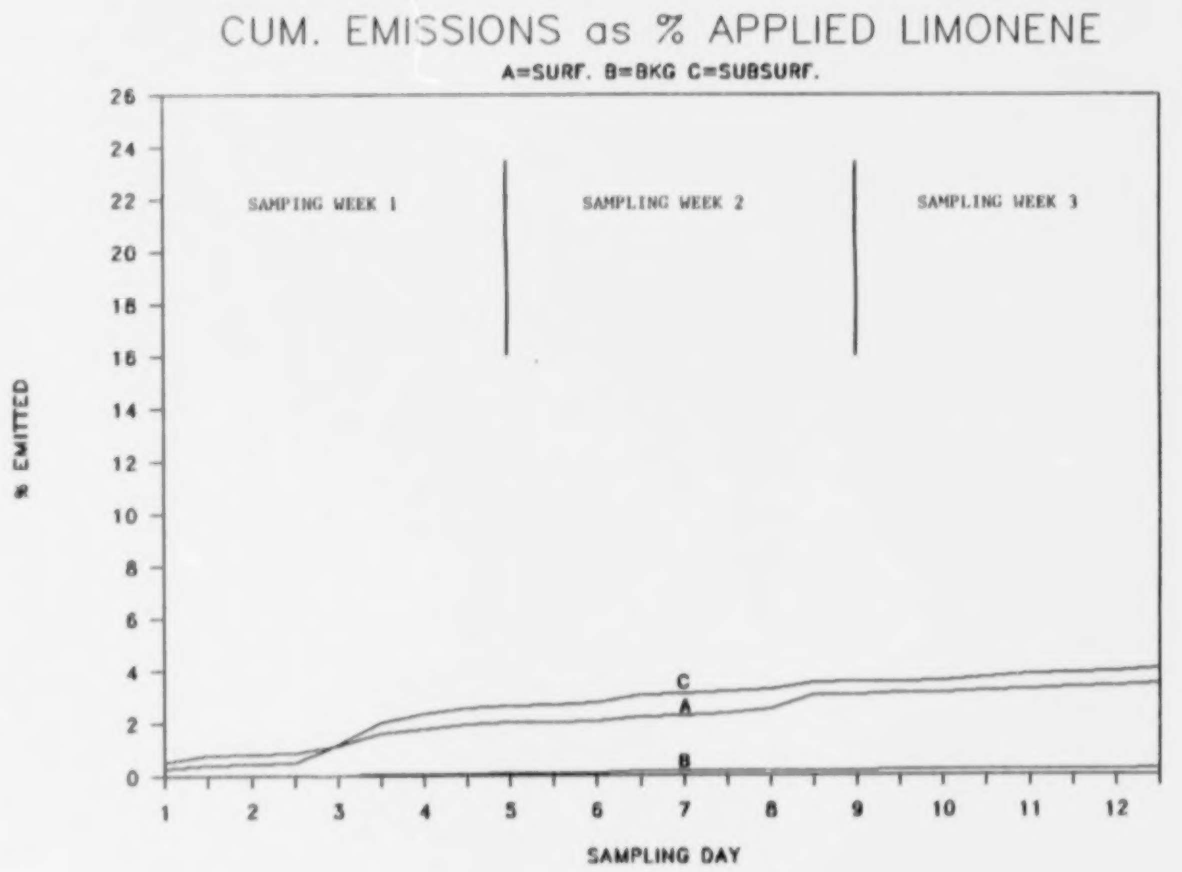


Figure 54. Cumulative measured emissions as the % of applied limonene (only days on which sampling was done are shown).

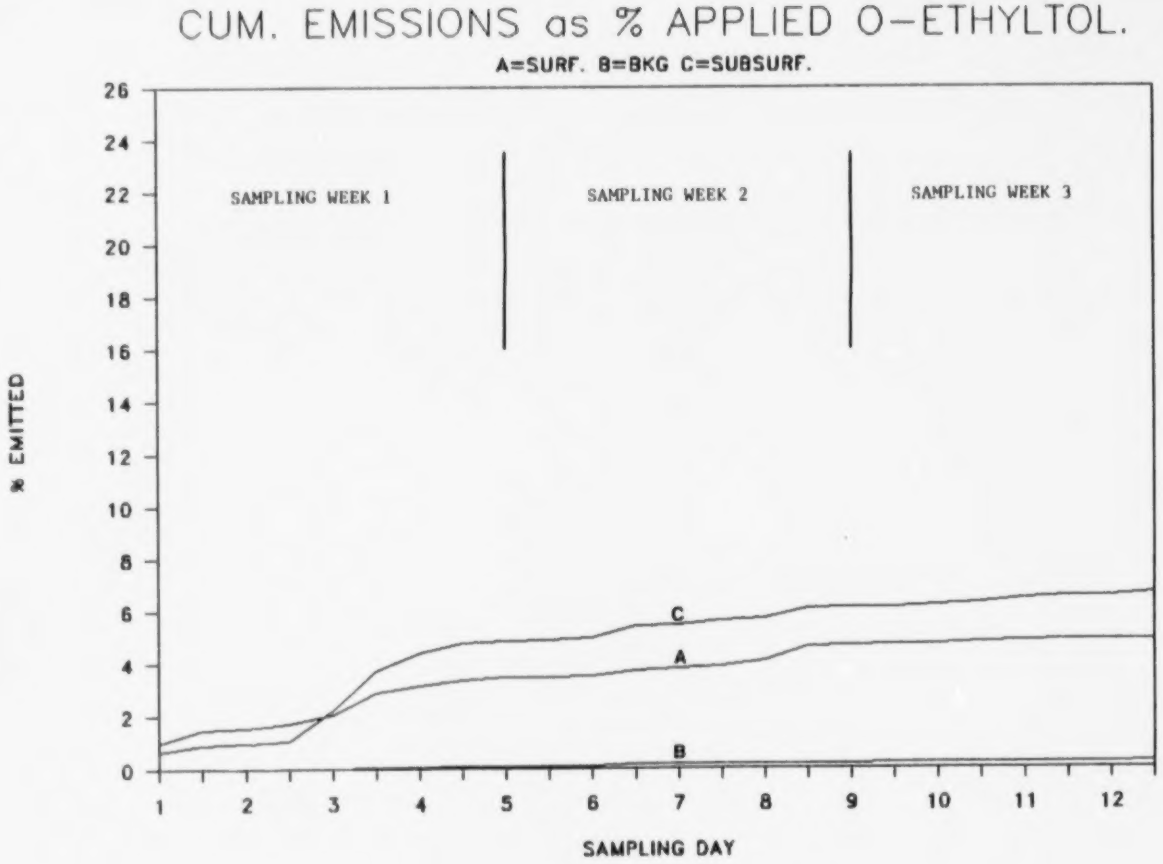


Figure 55. Cumulative measured emissions as the % of applied o-ethyltoluene (only days on which sampling was done are shown).

TABLE 28. CUMULATIVE MEASURED EMISSIONS OF SELECTED INDIVIDUAL COMPOUNDS

Compound	Cumulative Emissions (grams)			As Percent of Applied Compound		
	Plot A (Surface)	Plot B (Background)	Plot C (Subsurface)	Plot A (Surface)	Plot B (Background)	Plot C (Subsurface)
n-heptane	152	1.06	243	9.36	0.07	15.0
Methylcyclohexane	183	2.12	272	9.40	0.11	14.0
3-methylheptane	161	3.05	249	8.04	0.15	12.4
n-nonane	131	4.20	190	8.83	0.28	12.8
1-methylcyclohexene	32.0	0.802	56.2	6.97	0.18	12.2
1-octene	35.9	1.18	53.5	7.77	0.26	11.6
B-pinene	58.5	3.43	75.5	2.61	0.15	3.37
Limonene	39.3	2.73	45.8	3.47	0.24	4.04
Toluene	271	2.18	403	6.24	0.05	9.29
p-, m-xylene	219	3.22	311	5.59	0.08	7.93
1,3,5-trimethylbenzene	74.1	3.85	97.8	3.23	0.17	4.27
o-ethyltoluene	88.9	4.1	122	4.89	0.23	6.70

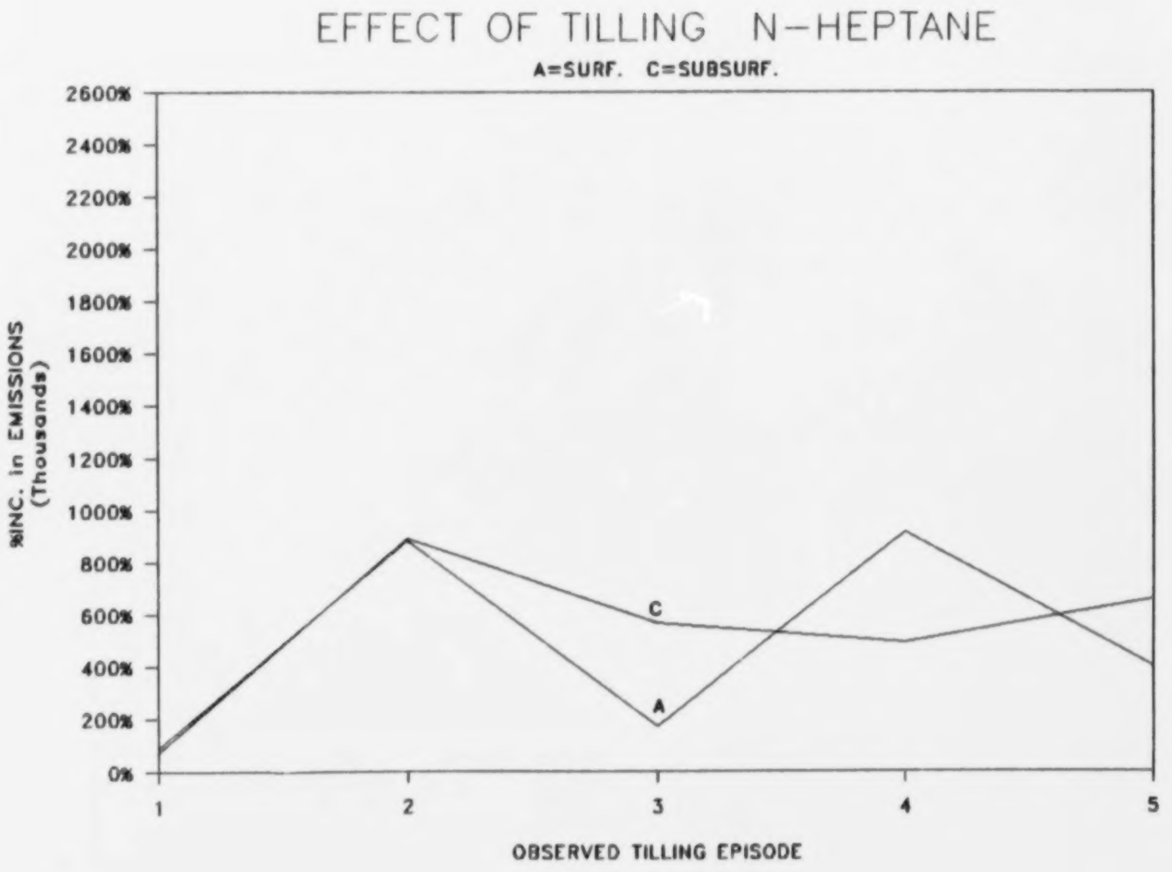


Figure 56. Effect of tilling on n-heptane.

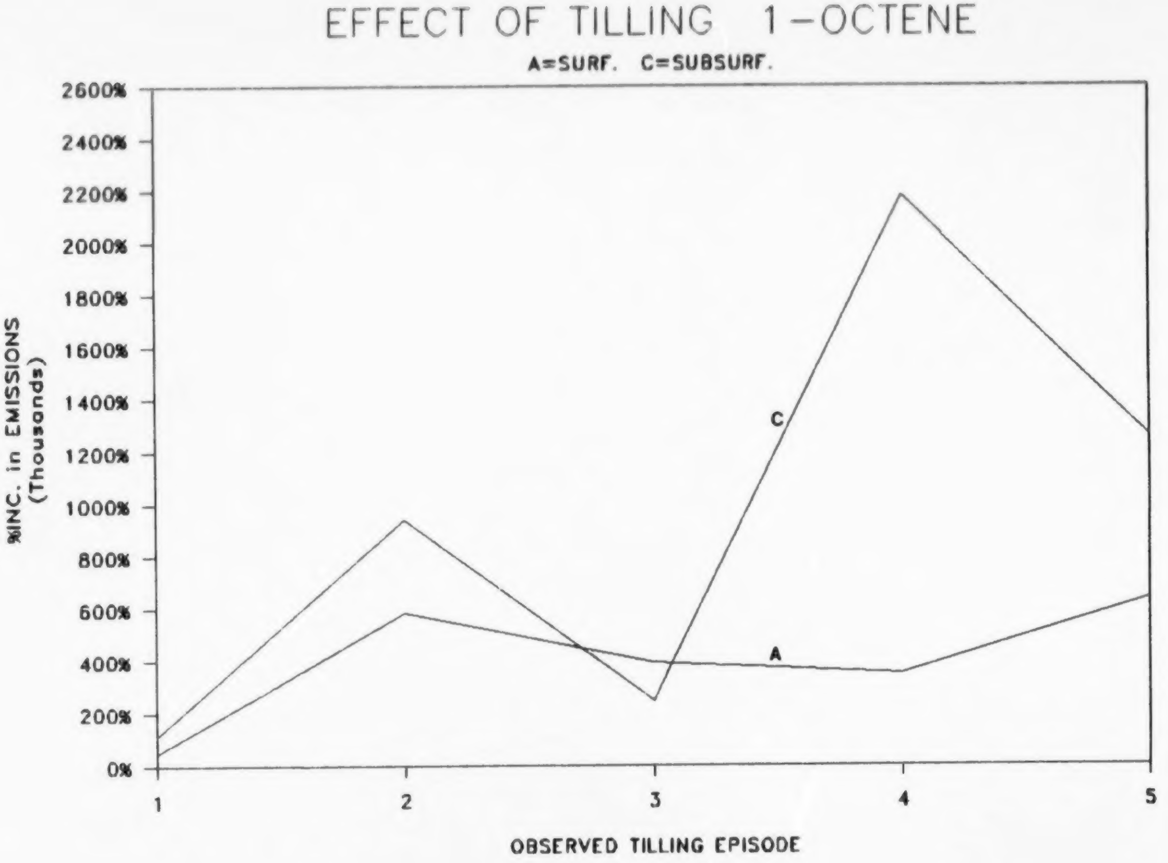


Figure 57. Effect of tilling on 1-octene.

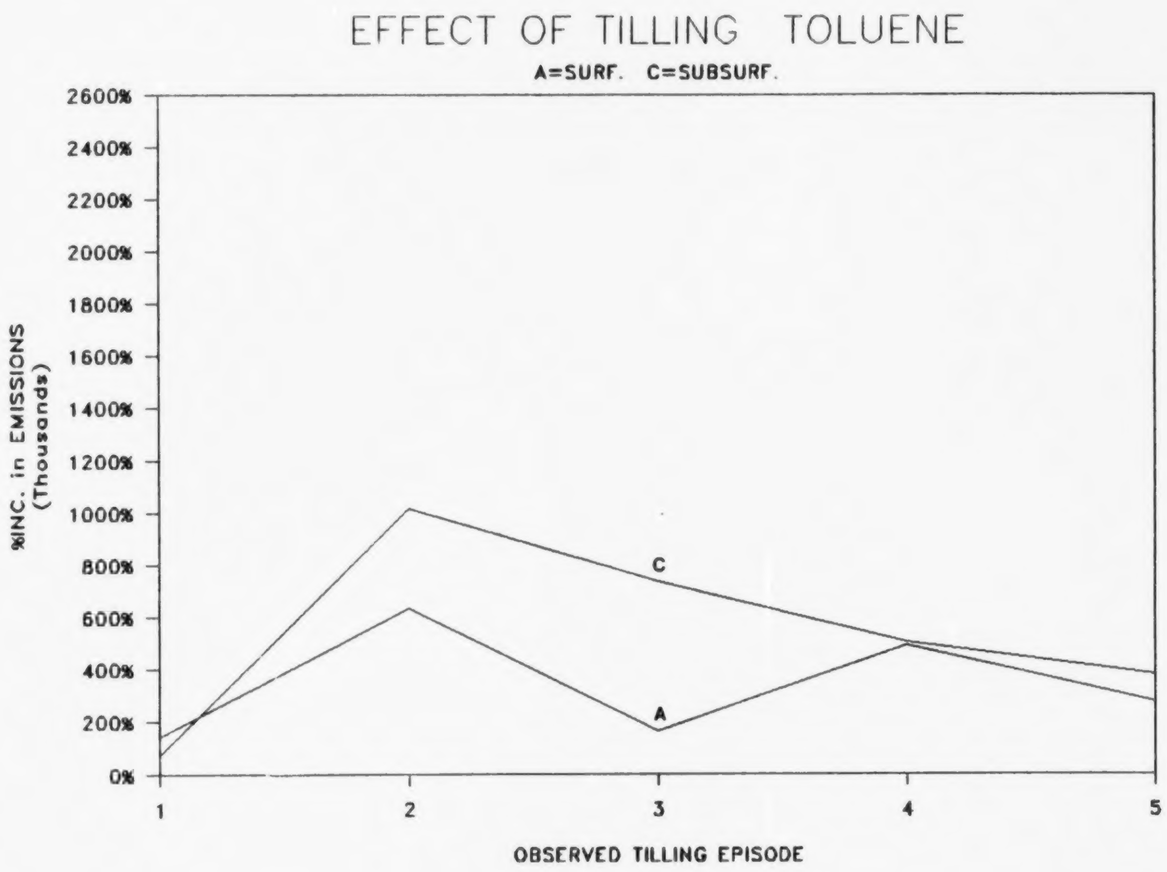


Figure 58. Effect of tilling on toluene.

TABLE 29. EFFECT OF TILLING ON EMISSION RATES OF INDIVIDUAL COMPOUNDS

		Percent Increase in Emissions				
Compound	Plot	10/12	10/24	10/26	11/09	11/12
n-heptane	Surface	88.1	882	173	915	401
	Subsurface	71.4	892	568	493	658
Methyl-cyclohexane	Surface	92.3	740	200	1780	876
	Subsurface	60.4	742	428	495	597
3-Methyl-heptane	Surface	109	853	189	2000	1230
	Subsurface	52.0	653	401	474	636
n-nonane	Surface	114	866	244	689	409
	Subsurface	28.2	441	419	315	629
1-Methyl-cyclohexene	Surface	67.4	778	323	1510	679
	Subsurface	51.6	0	348	332	556
1-Octene	Surface	112	940	246	2180	1260
	Subsurface	47.4	584	391	352	637
B-pinene	Surface	137	930	228	1390	643
	Subsurface	21.2	299	308	313	593
Limonene	Surface	89.9	895	295	1160	295
	Subsurface	15.0	236	245	319	556
Toluene	Surface	143	635	165	493	278
	Subsurface	74.9	1010	737	506	379
p-, m-xylene	Surface	103	728	175	694	238
	Subsurface	34.9	553	513	450	414
1,3,5-Tri-methylbenzene	Surface	113	859	234	1330	707
	Subsurface	19.1	316	47.3	324	563
o-ethyltoluene	Surface	117	853	214	1070	-17.0
	Subsurface	26.6	315	310	263	50.1
Total VOC	Surface	203	511	226	895	254
	Subsurface	146	804	356	311	299

pounds exhibit the same general range of values seen for the total volatile organics.

Estimated Total Emission Rates for the Test Period

The total emissions for each selected compound were calculated in a manner analogous to that for total volatile organic emissions described in Appendix H. Estimated total emissions are listed in Table 30. The same trends for total estimated emissions of individual compounds are similar to those seen for the measured emissions of these compounds.

BIODEGRADATION OF APPLIED OIL

Complete aerobic degradation of hydrocarbons will yield carbon dioxide and water. An effort was made to estimate the biodegradation rate of the oil applied to the land treatment plots by evaluating several factors, including:

- Evolution of methane from the soil;
- Presence of volatile products of partial degradation in the gases being emitted from the soil;
- Increased microbial population in the soil;
- Disappearance of oil in the soil; and
- Evolution of CO_2 from the soil.

These factors are discussed individually below.

Evolution of Methane

Methane in gas syringe samples collected from the flux chambers was determined on-site using the Byron 401 analyzer. Methane was not detectable in the sludge with the purge and trap GC system used. Therefore, the presence of methane in the air from the flux chambers would have indicated a methane source either in the soil or in the original applied sludge. Methane would have been produced if there had been significant anaerobic degradation of the applied oil. No methane was detected. Thus, it was concluded that oil was not significantly destroyed in the soil by anaerobic degradation.

Products of Partial Degradation

The composition of emitted gas from the landfarm was compared to the composition of the applied sludge to find any newly appearing compounds that might have been produced from partial degradation of the oil. This examination revealed an unidentified C_2 and cyclopentane in approximately three-quarters of the gas samples. Other "new" compounds detected in less than one-quarter of the gas samples included a C_2 butene, T-2 butene and 3-methyl-1-butene. All of these compounds were present in very small concentrations. If indeed they were products of partial degradation, the

TABLE 30. ESTIMATED TOTAL EMISSIONS FOR SELECTED COMPOUNDS

Compound	Amount Applied Per Plot (grams)	Relative Standard Error for Amount Applied	Total Estimated Emissions (grams)			As Percent of Applied Compound		
			Plot A (surface)	Plot B (Background)	Plot C (Subsurface)	Plot A (Surface)	Plot B (Background)	Plot C (Subsurface)
n-heptane	1624	27.3%	977	6.1	1520	60	0.38	94
Methylcyclohexane	1947	25.8%	1190	12.1	1720	61	0.62	88
3-methyl-heptane	2002	27.3%	1050	16.7	1550	52	0.83	77
n-nonane	1484	43.0%	838	24.30	1180	56	1.6	80
1-methylcyclohexene	459	33.8%	226	4.5	348	49	1.0	76
1-octene	462	30.0%	233	6.4	340	50	1.4	74
B-pinene	2240	45.4%	374	20.3	474	17	0.91	21
Limonene	1134	26.1%	253	16.0	291	22	1.4	26
Toluene	4340	22.7%	1620	12.2	2430	37	0.28	56
p-, m-xylene	3920	20.8%	1360	18.3	1890	35	0.47	48
1,3,5-trimethylbenzene	2292	20.2%	479	21.6	614	21	0.94	27
o-ethyl-toluene	1820	22.5%	582	24.6	758	32	1.4	42
Total VOC	109,800		33,300	5,200	39,000	30	4.7	36

amount of oil disappearance accounted for by these compounds was negligibly small.

Partial degradation of hydrocarbons may yield some oxygenated compounds such as fatty acids. Very low concentrations of some of these compounds may not be detected by the GC method utilized in this study. It is possible, then, that some small quantities of oxygenated compounds could have escaped detection. It is very unlikely, however, that these small quantities would have accounted for a significant amount of oil degradation.

Microbial Population

It might be expected that an increase in the microbial population of the soil would indicate increased biological activity and consequent degradation of the oil in the soil. The microbe levels in the soil have been plotted as functions of elapsed time and the CO_2 concentration (in the flux chamber) in Figures 59 and 60, respectively. There does not appear to be a significant relationship between the CO_2 concentration and the microbe level. As shown in Figure 59, the microbial population does not evidence any clear pattern with respect to the elapsed time. The population data are quite scattered, however, and this variability may mask any modest pattern.

Disappearance of Oil in the Soil

Significant degradation of the oil in the soil should be indicated by a detectable decrease in the oil content of the soil as degradation proceeds. The average oil (and grease) content of the soil was determined for each sampling interval for each of the three plots. The results are tabulated in Table 31. There is no apparent decrease in the mean oil content with time of any of the three test plots. However, the variability of the oil content from point-to-point in the plots results in very wide confidence intervals about the mean oil concentrations. The variability is clearly evident in Figure 61 in which the individual concentrations are plotted as a function of time.

Part of the variability in the oil content is undoubtedly due to the natural unevenness of application. Some of the uncertainty, however, may be inherent in the analytical method used in determining the levels of oil and grease in the soil samples. Radian used EPA Method 413.1 in the analyses. This is an extraction/gravimetric method in which Freon-113 is used as the extracting agent. The Freon-113 is then evaporated, and the residue is weighed as the oil and grease. Volatile organics can be lost in the drying step.

Chevron Research Corporation (CRC) obtained soil samples from the same locations and at the same times as Radian. CRC also took additional soil samples from emission sampling points in the plots. In their determination of the oil content of the soil samples, CRC used a modified oven drying technique (MODT), which they developed (Appendix P). This technique appears to provide more accurate and precise analyses for oil content of soils and sludges. Chevron's results are presented and discussed in Appendix A. CRC's

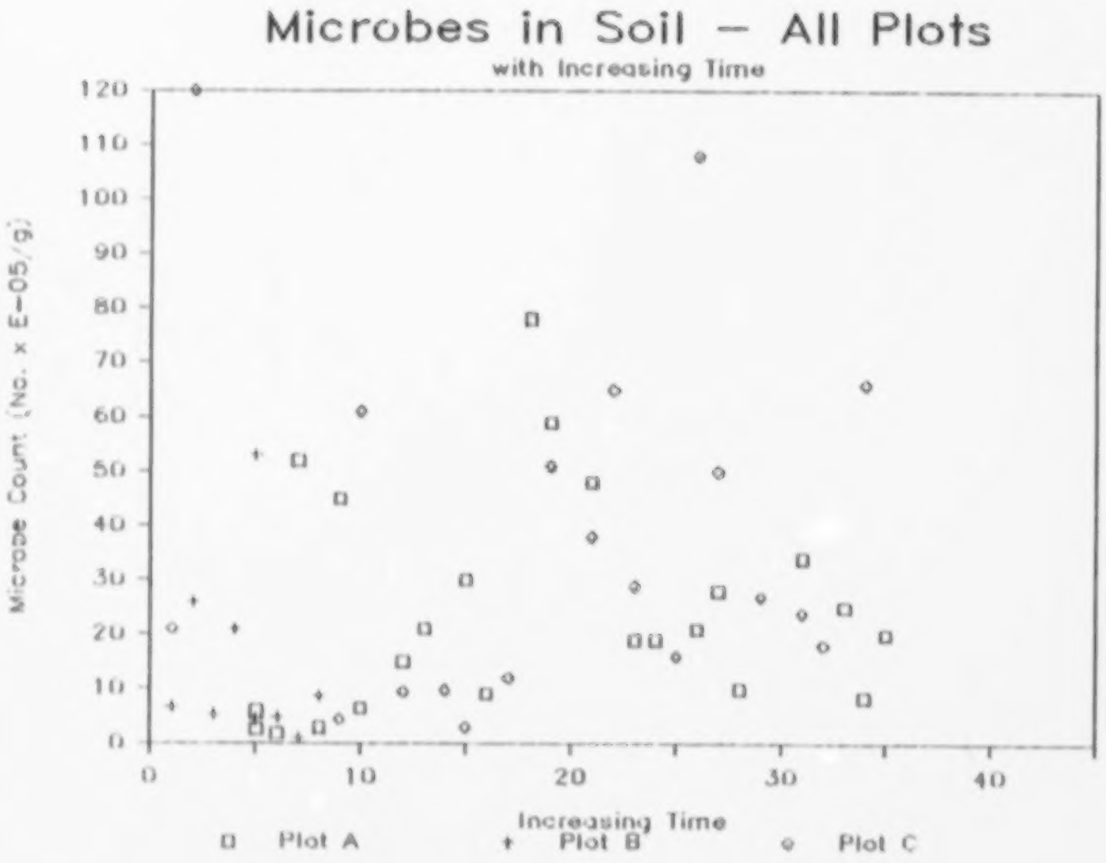


Figure 59. Microbes in soil with increasing time (all plots).

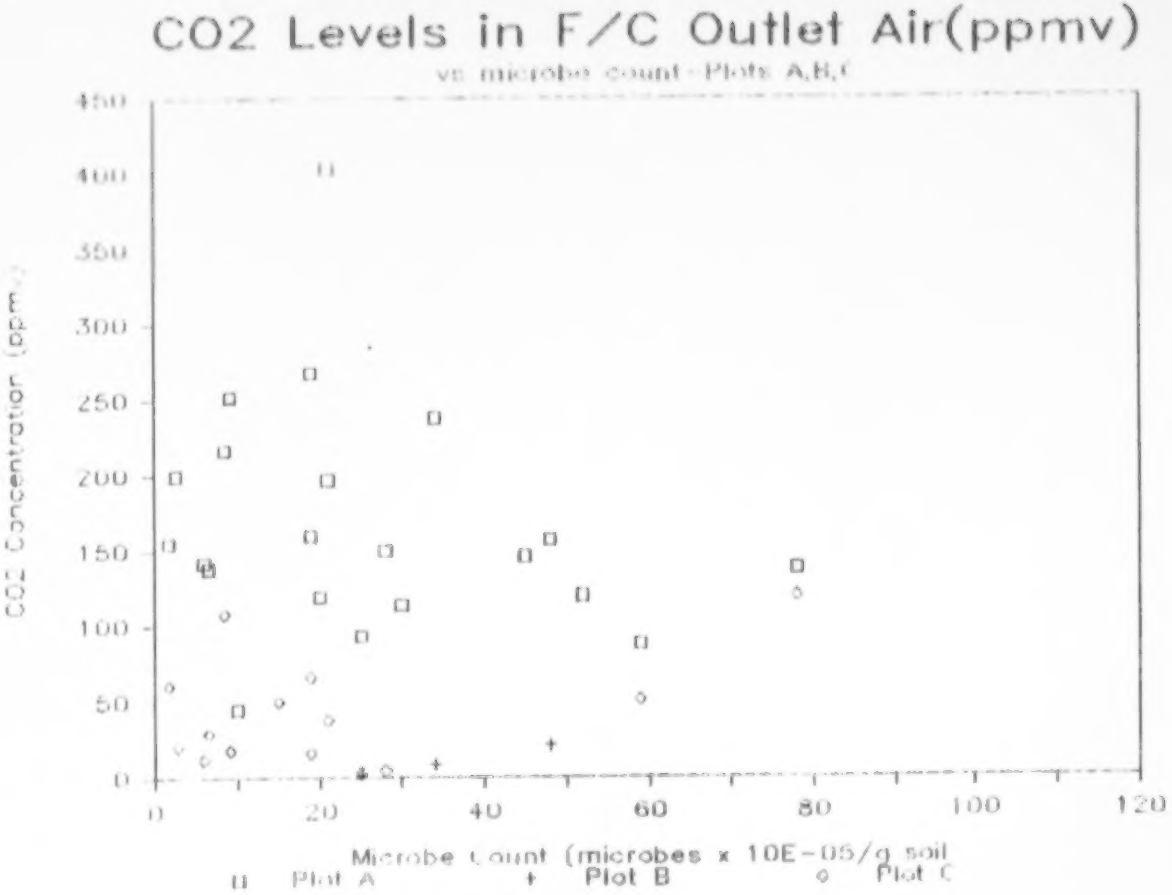


Figure 60. CO_2 levels in flux chamber outlet air in ppmv vs. microbe count (Plots A, B, and C).

TABLE 31. OIL CONTENT OF SOIL SAMPLES

Plot	Sampling Period	Moisture Content, Wt. %	Oil Content (Wet), mg/g	Oil Content (Dry), mg/g
A	10/10 - 10/13	11.7 ± 3.6	49 ± 25	59.2 ± 22.2
	10/23 - 10/26	9.6 ± 0.8	63 ± 14	69.9 ± 14.9
	11/7 - 11/12	11.0 ± 1.3	55 ± 15	61.7 ± 16.4
B	10/10 - 10/13	9.3 ± 0.5	44 ± 9	49.0 ± 10.0
	10/23 - 10/26	8.7 ± 0.8	45 ± 3.2	
	11/7 - 11/12	10.4 ± 0.6	52 ± 6	58.0 ± 7.0
C	10/10 - 10/13	10.7 ± 1.4	46 ± 12	51.7 ± 14.0
	10/23 - 10/26	9.1 ± 0.7	68 ± 26	74.7 ± 27.8
	11/7 - 11/12	10.9 ± 1.5	55 ± 11	61.5 ± 12.4

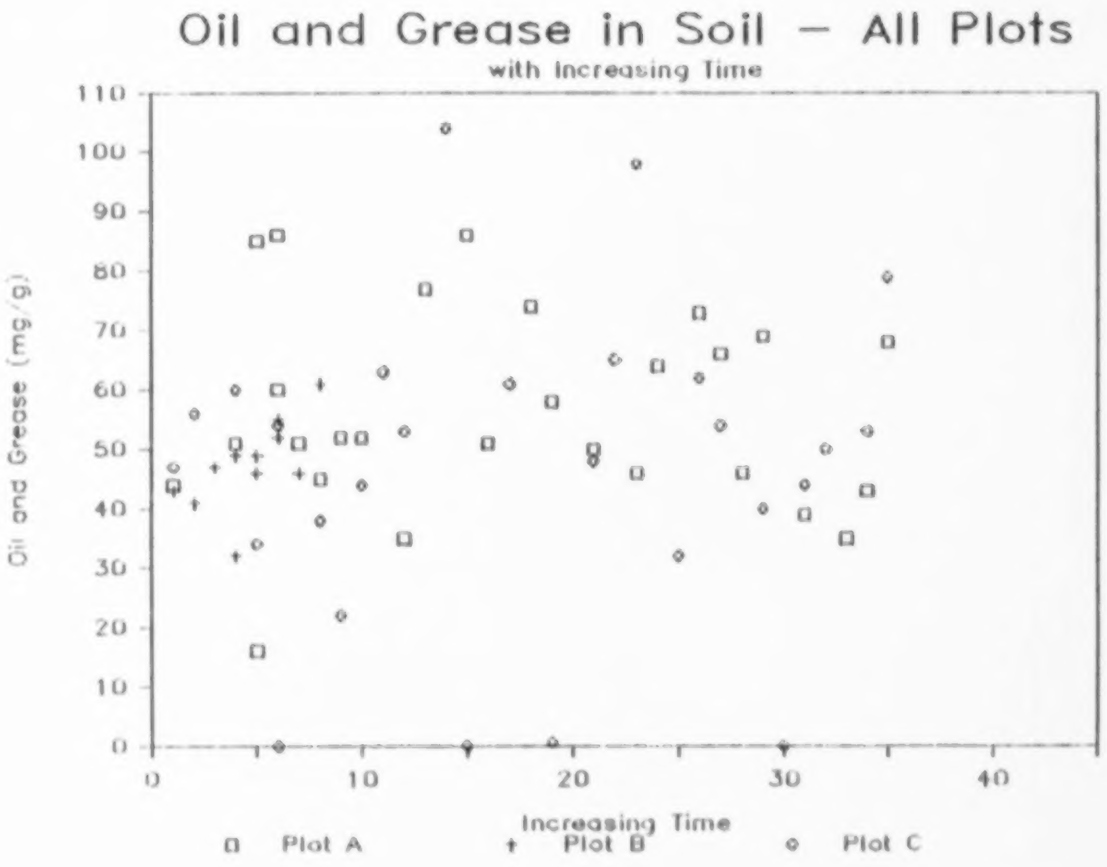


Figure 61. Oil and grease in soil with increasing time (all plots).

results were generally higher than Radian's. Such a result would be consistent with possible loss of material during Radian's analyses.

It should also be noted that biodegradation of oil to CO_2 and possible volatile intermediate products may not be the only means by which oil may be converted to other materials. Oil may be degraded by humification, i.e., the conversion of solvent-extractable hydrocarbons and hydrocarbon metabolites to solvent-insoluble soil organic matter. Some evidence for this phenomena was seen in a recent study of sludge degradation in soil (11).

Evolution of CO_2

The CO_2 concentrations in the air from the flux chamber were measured during the monitoring periods to provide a basis for estimating the amount of applied oil which was completely degraded. The measured concentrations of CO_2 in the flux chamber effluent air have been presented in Table 4. These are the total CO_2 concentrations and include any background CO_2 as well as that produced as a result of biodegradation. Background CO_2 levels of 3-253 ppmv were determined throughout the duration of the testing. Possible sources of background CO_2 may have included residual ambient air and/or desorbed CO_2 from the flux chamber and associated equipment. The mean background concentration of CO_2 was determined to be 65 ppmv.

It was necessary to determine the effects (or lack of effects) of several parameters on the CO_2 evolution rate so that a mean rate could be estimated for the entire five-week test period. The effect of several variables on the emission rates was examined to provide a basis for estimating a mean evolution rate.

Elapsed Time--

The measured carbon dioxide evolution rate was plotted as a function of elapsed time (after sludge application) to provide a visual estimate of any trends. A scatter plot such as this often will show any apparent trends or patterns of behavior. If patterns are indicated, a more detailed statistical analysis may be warranted. The resulting graph is shown in Figure 62. The numbers 0 through 100 shown along the horizontal axis refer only to the time sequence in which the measurement occurred. The data for all three four-day test periods and for all three test plots are included in Figure 62. It is clearly evident from the figure that the carbon dioxide evolution rates are not a function of elapsed time. No further statistical analyses were performed.

Time of Day--

Since the temperature, soil moisture, humidity, etc., may all vary with the time of day, the carbon dioxide evolution rate was plotted as a function of the time of day. This graph is presented in Figure 63. No discernable relationship is evident from this graph.

Temperature--

Biological activity (i.e., degradation rates) should be a function of temperature, with the activity increasing with temperature. In the case of

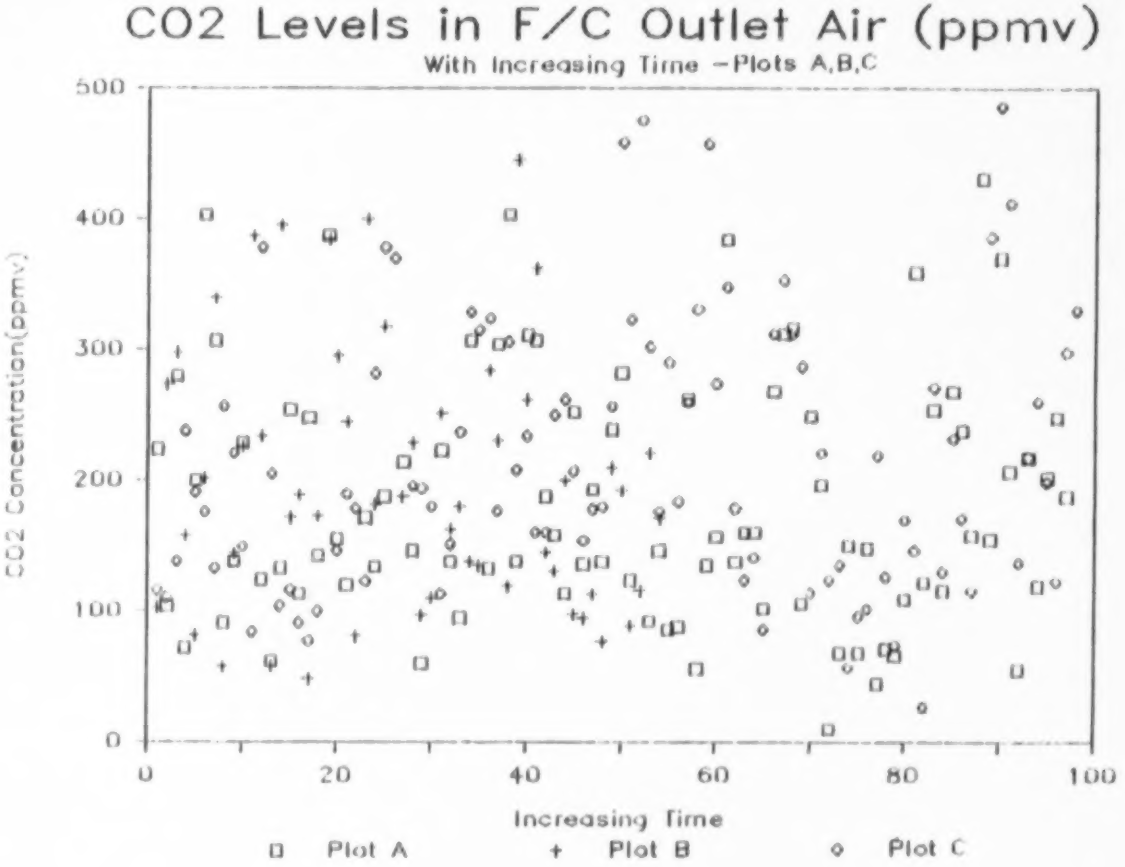


Figure 62. CO_2 levels in flux chamber outlet air in ppmv with increasing time (Plots A, B, and C).

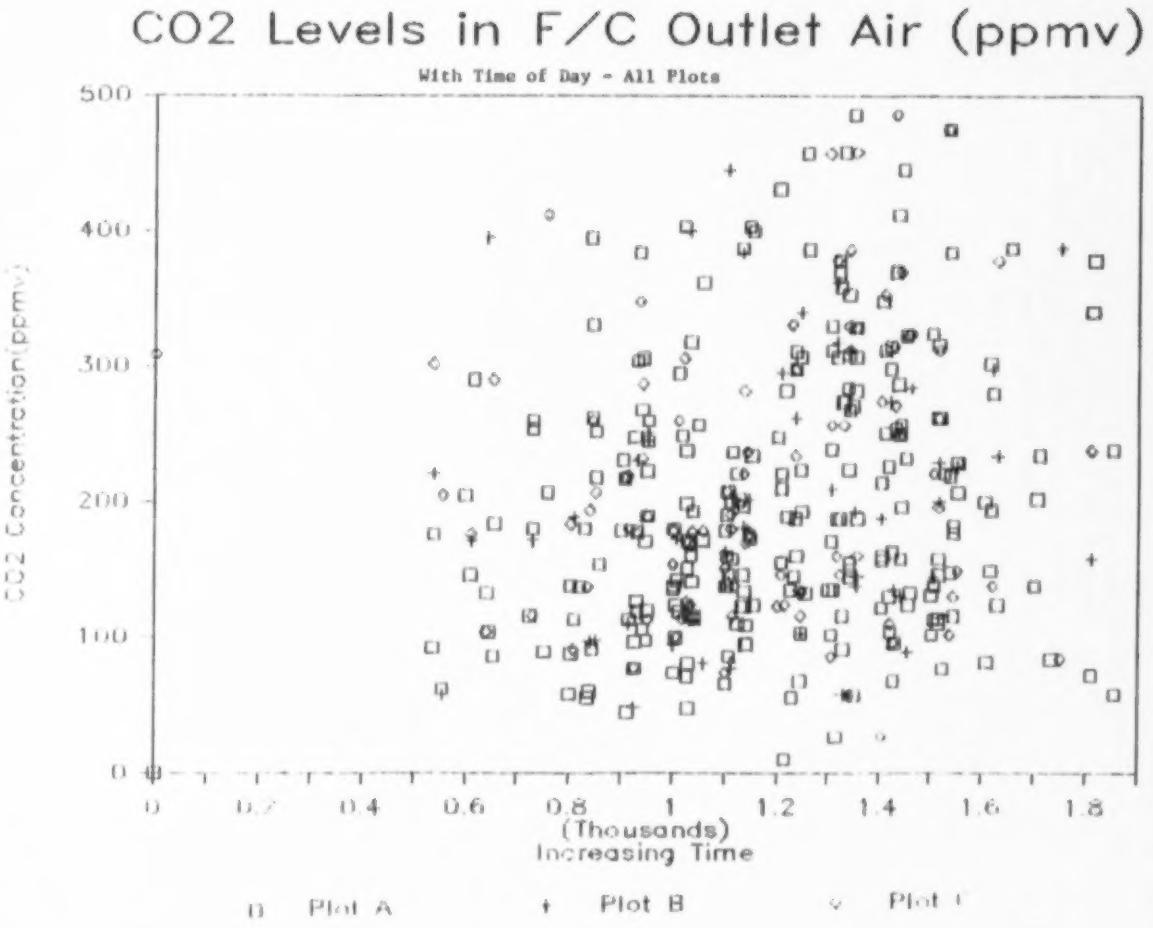


Figure 63. CO_2 levels in flux chamber outlet air in ppmv with time of day (all plots).

degradation in soil, the soil temperature should have some effect on the oil degradation rate. If the degradation rate of oil is affected by soil temperature, the evolution rate of carbon dioxide should be likewise affected.

A number of temperatures were routinely measured during the test program. These included soil temperature (surface), ambient air temperature, and air temperature within the flux chamber. The measured evolution rate of carbon dioxide was plotted in Figures 64 through 66 as a function of the various measured temperatures. These scatter plots do not indicate any relationships between the temperatures and the carbon dioxide evolution rates. The subsurface temperatures were not regularly measured, however. It is very probable that the temperatures below the surface of the soil varied within a much narrower range than any of the routinely measured temperatures. This behavior may account for the apparent lack of response of the carbon dioxide evolution rate to changes in the air and soil surface temperatures.

Moisture Level in the Soil--

Chevron regularly irrigates the land treatment area with water to maintain a moderate level of moisture in the soil. If the moisture level affected the biological activity (and, consequently, the evolution rate of carbon dioxide), the effect should be considered when estimating the carbon dioxide evolution rate over the five-week period.

The moisture content of the soil during the sampling periods is shown in Figure 67. Although the moisture content is somewhat scattered, the level is generally maintained between 8 and 12%. The carbon dioxide evolution rate was plotted as a function of the soil moisture content to detect any functional relationship at the existing moisture levels. As evident in Figure 68, there does not appear to be any discernable relationship between the two parameters.

Estimated Rates for Complete Aerobic Degradation

Compounds having 10 carbon atoms were the highest molecular weight detected during the analysis of the volatile organics in the sludge. Since the volatile organics content of the sludge is only about 2 weight percent (as defined by the purge-and-trap method), it is evident that most of the oil in the sludge is higher in molecular weight than C_{10} compounds. Chevron Research Corporation provided EPA with a simulated ASTM D 2287 distillation of the oil in the sludge (Appendix A). The mid-point (50% distilled) distillation temperature was 667-678°F, which is approximately equivalent to the boiling point of the paraffin eicosane ($C_{20}H_{42}$). Therefore, eicosane was selected as representative for calculational purposes.

Complete aerobic degradation or oxidation of eicosane can be represented by the following equation:

$$C_{20}H_{42} + 30.5\ O_2 \longrightarrow 20CO_2 + 21H_2O \qquad (13)$$

The degradation rates can then be estimated from the carbon dioxide emission rates measured with the flux chamber. The rates were calculated under the

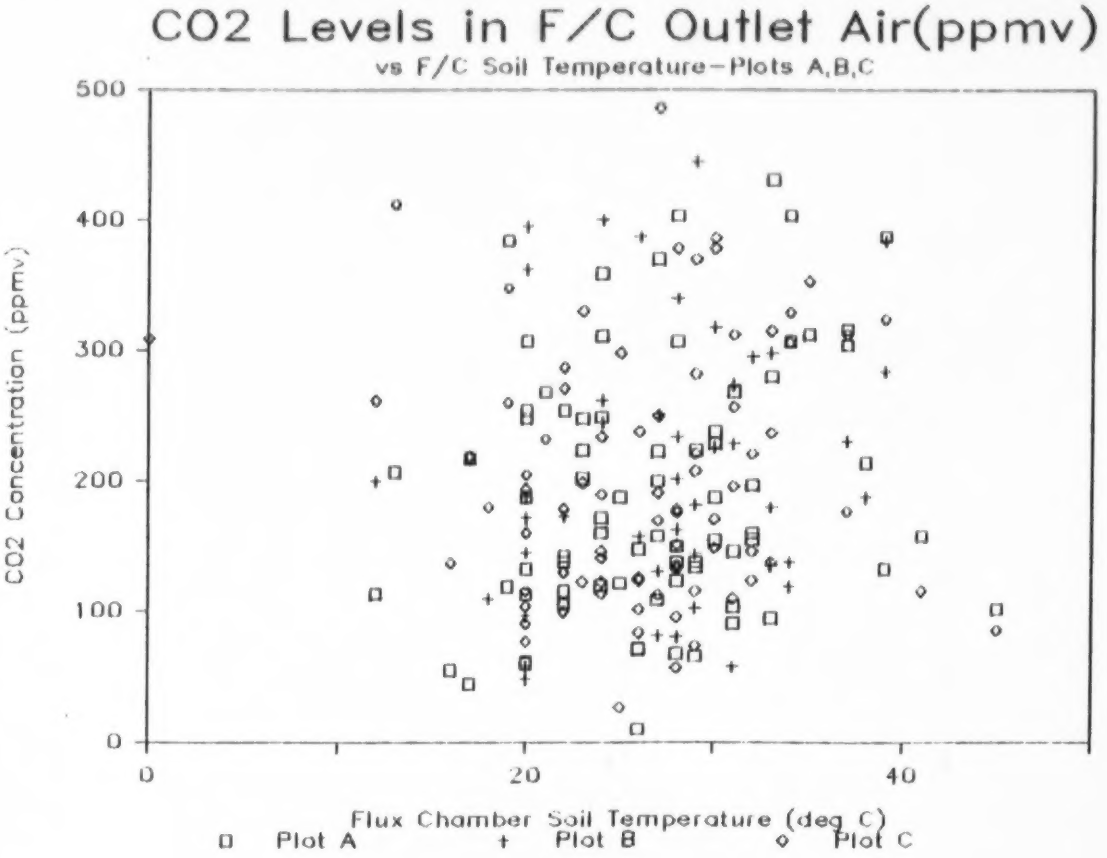


Figure 64. CO_2 levels in flux chamber outlet air in ppmv vs. flux chamber soil temperature (Plots A, B, and C).

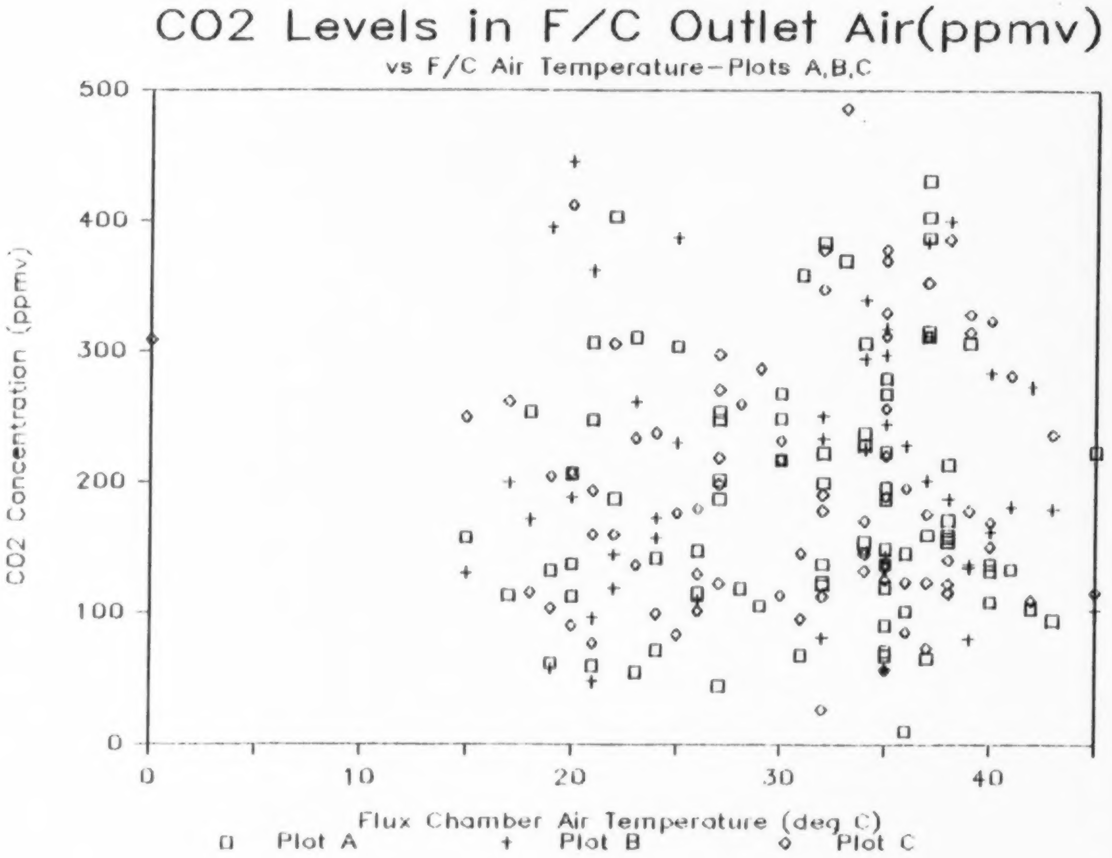


Figure 65. CO_2 levels in flux chamber outlet air in ppmv vs. flux chamber air temperature (Plots A, B, and C).

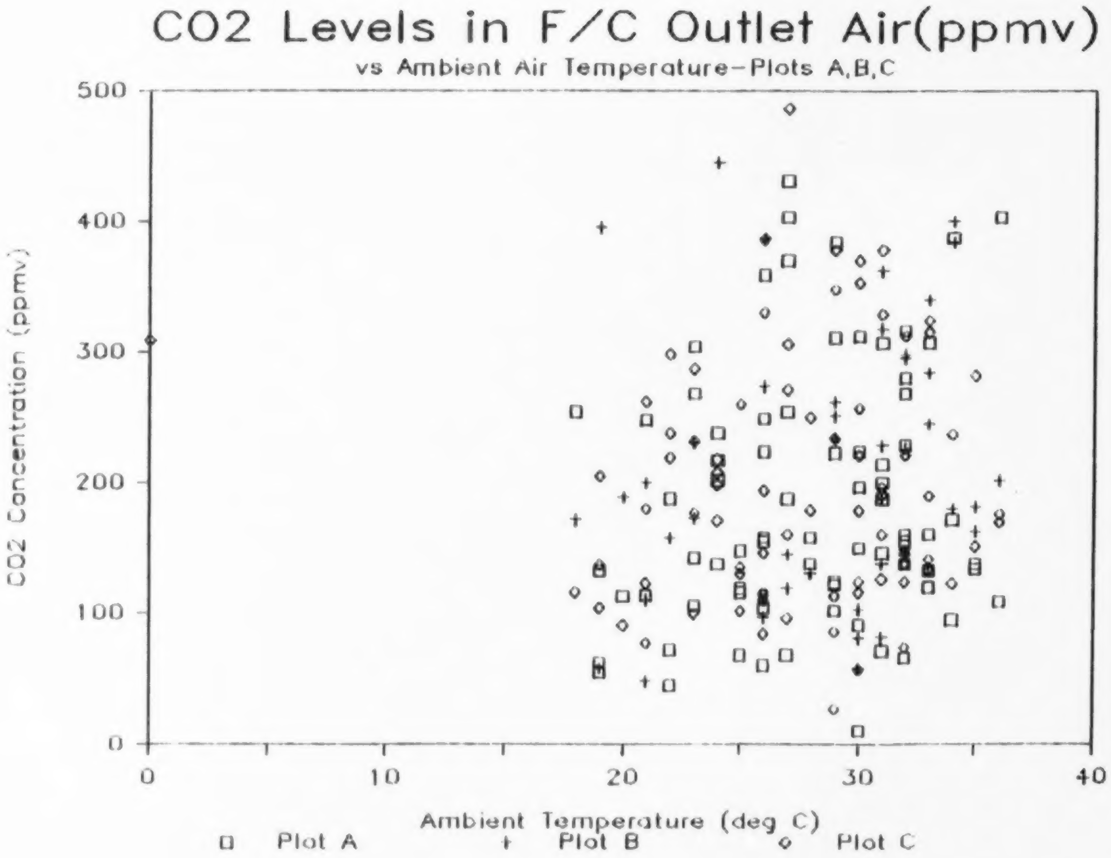


Figure 66. CO_2 levels in flux chamber outlet air in ppmv vs. ambient air temperature (Plots A, B, and C).

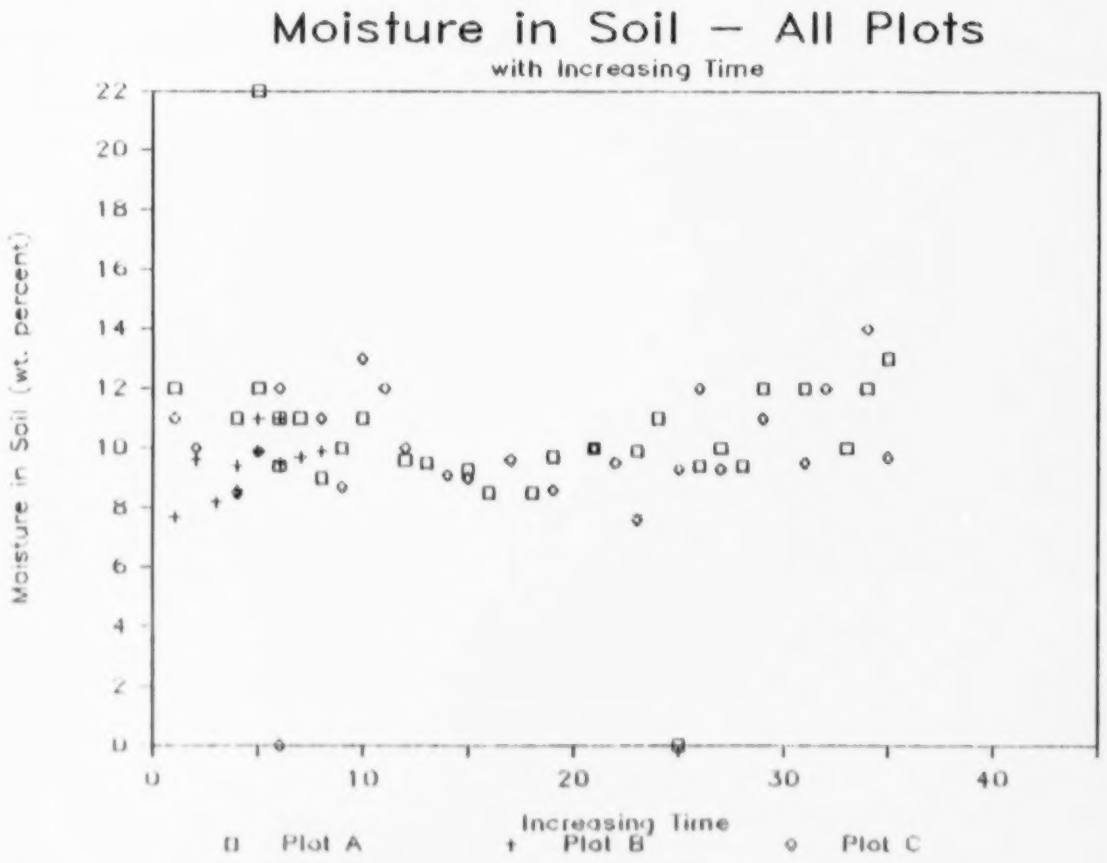


Figure 67. Moisture in soil with increasing time (all plots).

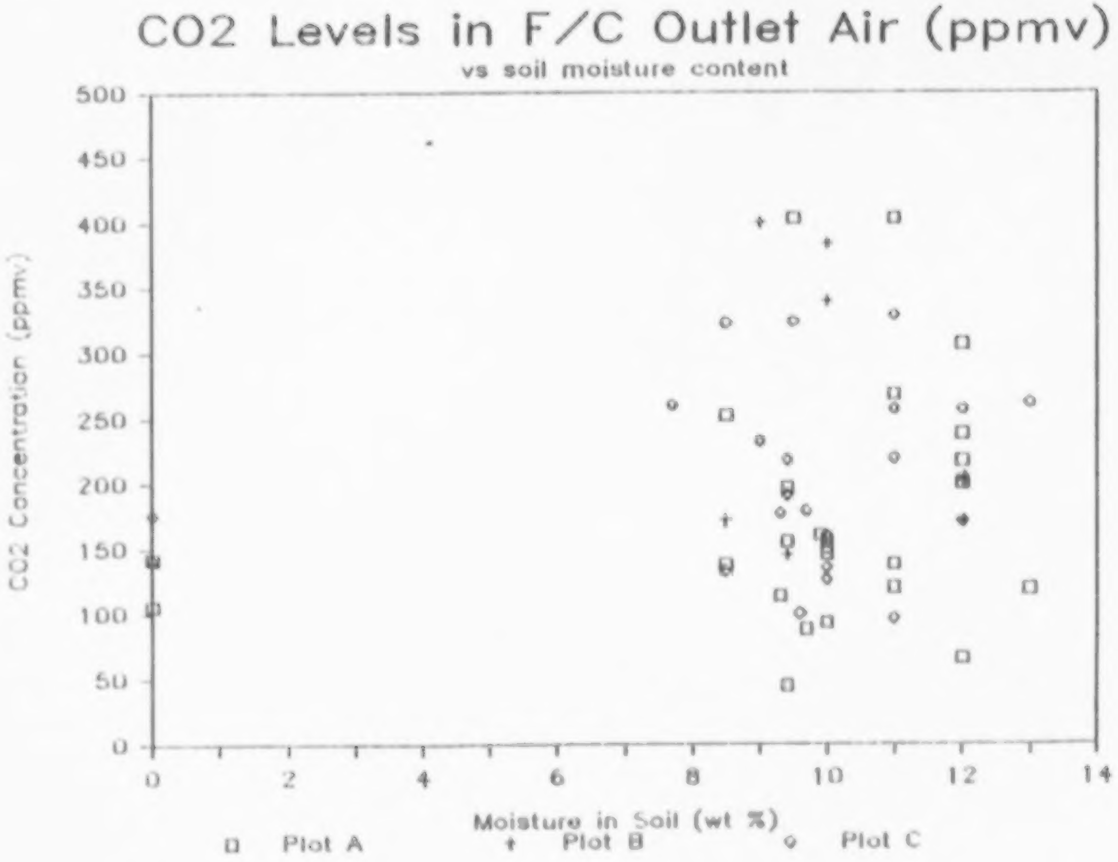


Figure 68. CO_2 levels in flux chamber outlet air in ppmv vs. soil moisture content.

assumption that all the carbon dioxide seen in the air from the flux chamber was produced as a result of biodegradation. The mean concentration of carbon dioxide in the air from the flux chambers was 200 (2, 398) ppmv, with the numbers in parentheses being the limits of the 95% confidence interval. Thus, the calculated degradation rates may be high by almost 50% because background levels of carbon dioxide (mean background level was 65 ppmv) were not subtracted from the measured concentrations before the degradation rates were calculated.

It is also quite possible that the soil may contain adsorbed carbon dioxide in equilibrium with the carbon dioxide in the atmosphere. If such is the case, some of this carbon dioxide might be desorbed when the soil is exposed to the carbon dioxide-free air in the flux chamber. Any desorbed carbon dioxide would also be interpreted as resulting from oil degradation.

The calculated cumulative degradation rates, expressed as grams of oil per square centimeter, are plotted as a function of increasing elapsed times in Figures 69 through 71. The abcissa of each graph is the sample sequence number, so the cumulative degradation is only for the sampling periods. These figures show, however, that the rate of degradation is relatively constant over the periods when sampling was performed. It should again be noted that the background CO_2 concentrations were not subtracted in these rate calculations. Had they been excluded, the slopes of the curves would have been significantly less. The average degradation rates were calculated for all three test plots, both before and after sludge application. These average rates are shown in Table 32. There does not appear to be a statistically significant difference between any of the calculated rates. The mean rate from all three plots was 0.290 g/hr-m^2. If this rate is assumed to be in effect for the entire five-week test period, the amount of oil degraded to carbon dioxide and water is equivalent to 240 g/m^2. This represents approximately 3.7 weight percent of the applied oil or less than 1 weight percent of the applied sludge.

Since the methane concentrations in the flux chamber air were below 1-2 ppmv, the potential contribution of complete anaerobic degradation appears to be negligible.

EFFECT OF APPLICATION METHOD ON VOC EMISSIONS

Immediately after sludge application, the measured emission rates from the surface application plot appeared to be slightly higher than those measured from the subsurface application plot. After the first tilling episode, two days after the initial application, the measured rates from the subsurface application plots seemed to be slightly higher than those of the surface application plot. Because of the variability in measured emission rates with both time and grid point within each plot, however, it is difficult to draw conclusions regarding their relative emission performance with any reasonable degree of confidence. For all practical purposes, the emission behavior of the subsurface and surface application plots was identical.

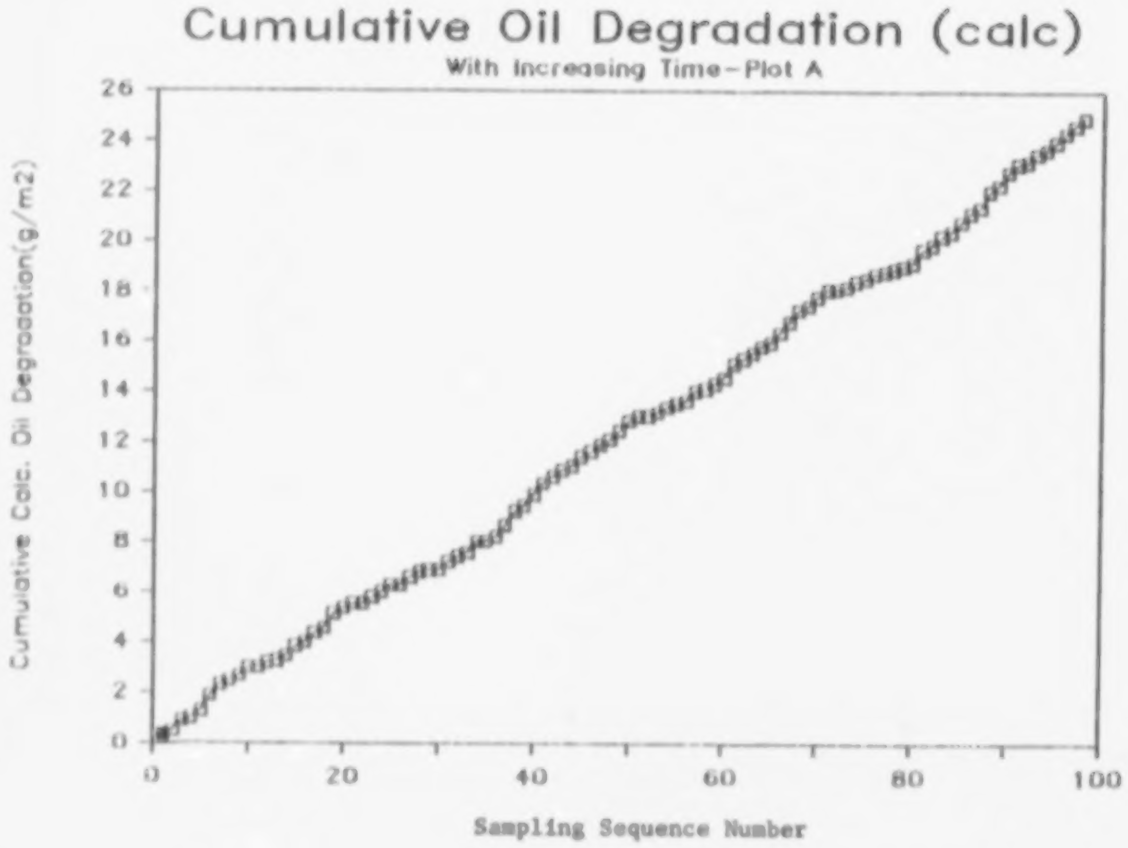


Figure 69. Measured cumulative oil degradation (assuming oil represented as n-octane) - Plot A.

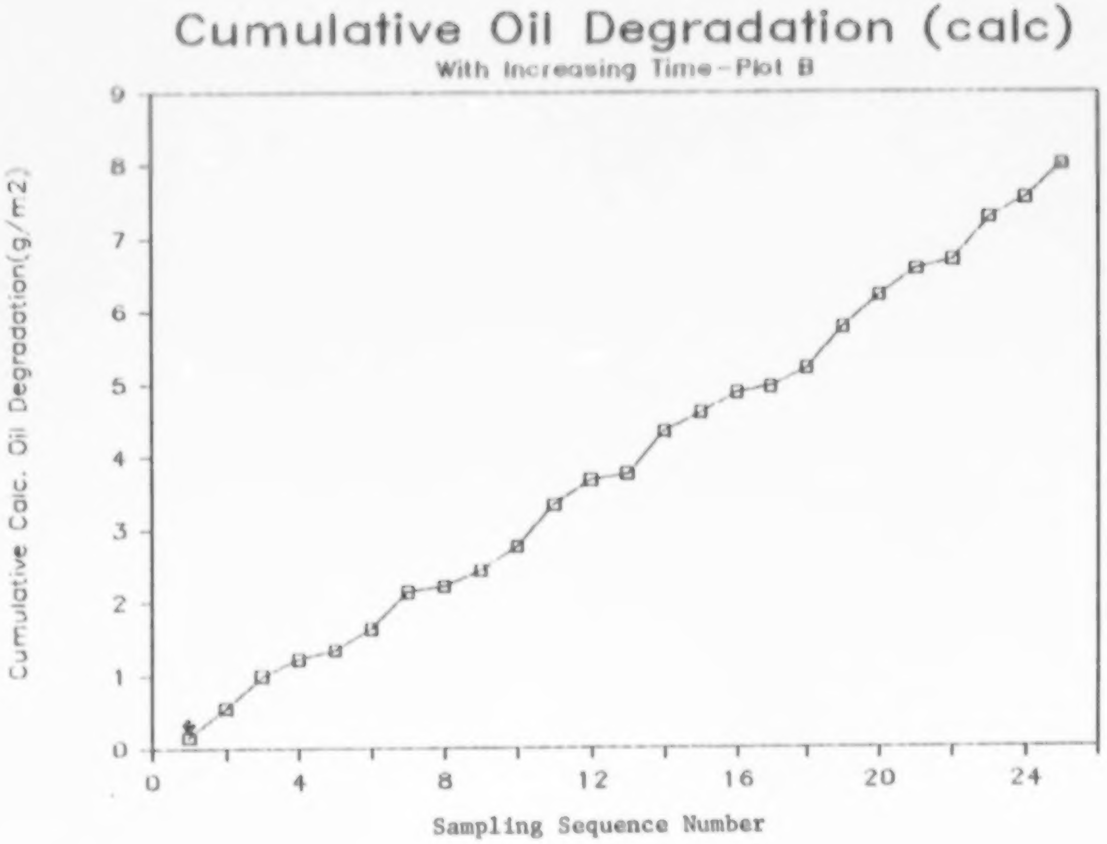


Figure 70. Measured cumulative oil degradation (assuming oil represented as n-octane) - Plot B.

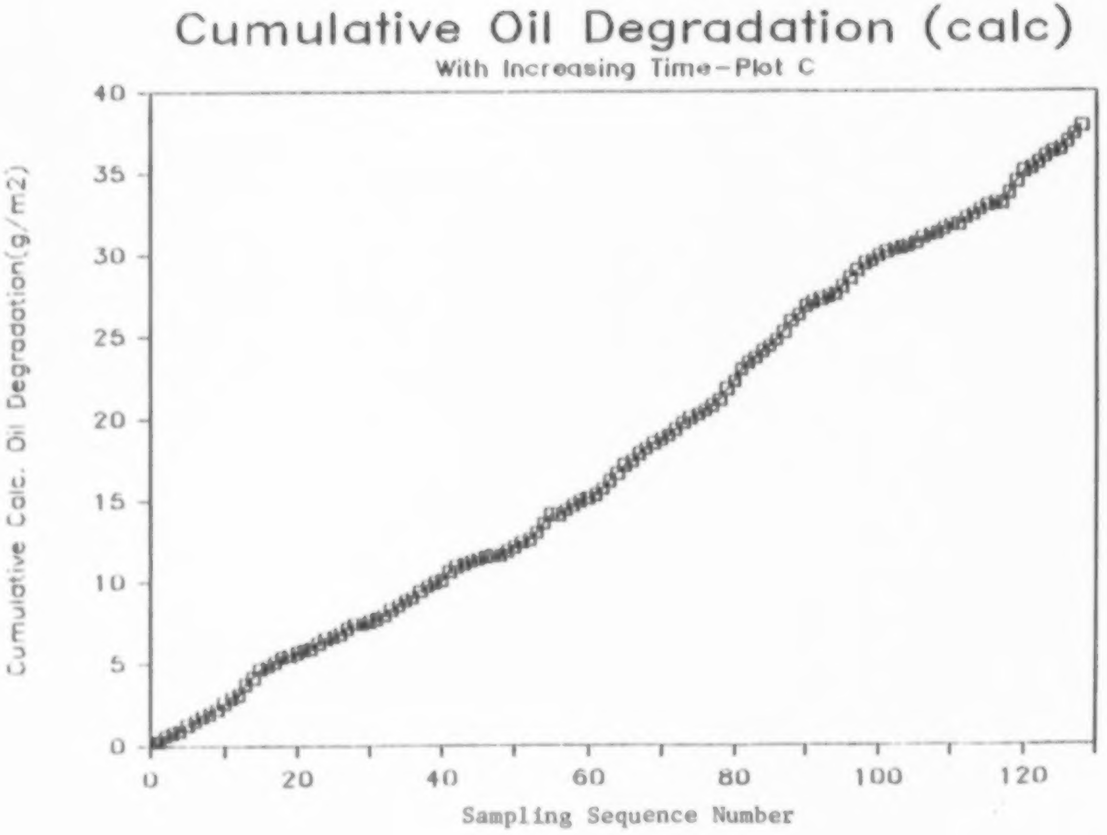


Figure 71. Measured cumulative oil degradation (assuming oil represented as n-octane) - Plot C.

TABLE 32. MEAN DEGRADATION RATES OF APPLIED OIL ESTIMATED FROM CO_2 EVOLUTION

	Estimated Oil Degradation Rates[a], gr/hr-m^2	
Test Plot	Before Sludge Application	After Sludge Application
A	0.218 (0.006, 0.574)[b]	0.267 (0, 0.539)
B	0.274 (0, 0.581)	0.287 (0, 0.577)
C	0.219 (0.045, 0.464)	0.312 (0.019, 0.562)
	Mean Rate	0.290 (0.003, 0.580)

[a] Oil assumed to be $C_{20}H_{42}$

[b] Values in parentheses are limits of 95% confidence interval

Upon first examination, this identical behavior is somewhat surprising, because one laboratory study (12) indicated significantly lower land treatment emissions as a result of subsurface injection, at least for the short (8-hour) period immediately following application. However, at Chevron, both the surface- and subsurface-applied plots were tilled immediately after application. Even after the initial application, the surface of both plots visually appeared to be quite similar. This visual similarity became more evident with each tilling episode, until there was no visible difference between the appearance of the plots.

Effect of Application Method on Annual Emissions Rate

One project objective was to determine the effect of using subsurface injection instead of surface application on emissions rates. Radian's field study results indicate that, to within experimental error, there is no difference in emissions rates of five-week periods. These data suggest that there would be no significant difference in emissions over a year, either.

In order to determine how large the annual emissions reductions at this site might be if an effective emissions control technique (e.g., by treating the waste to remove volatiles) was found, annual emissions for 1984 are estimated. The major assumptions are presented here and detailed calculations are provided in Appendix Q. A discussion of the significance of selected assumptions is provided.

The estimate was made under the following assumptions:

1. The total sludge applied to the Chevron El Segundo land treatment site in 1984 was 2,896 tons consisting of the following types:

API Separator/DAF Sludge	-	2,557 tons
Tank Bottoms	-	201 tons
Unspecified Sludges	-	138 tons

   as reported in EPA data (13);

2. The volatile organic content of all the sludge was the same as that of the sludge applied to the test plots (i.e., approximately 0.8% of the applied sludge or about 4.0% of the applied oil);

3. The sludge was applied throughout the 40,470 m^2 (10 acre) facility at a rate equal to that of application to the test plots: 33 kg/m^2. At this rate, approximately two applications to the whole facility would have been made to apply 2,896 tons. Since the facility is operated for approximately 8 months out of the year, the applications would be 4 months (120 days) apart.

4. The emission period is assumed to last 120 days. Sludge had

last been applied to the control Plot B in June (assumed to be June 15). Emissions from this plot were still being measured at the end of the current test period 116 days later, or approximately 120 days.[1]

5. The total emission rates for the first 33 days following the application of sludge were the same as the average of the estimated rates for Plots A and C (since emissions were not significantly different).

6. The emission rates for days 34-120 were the average of (1) the Plots A and C emissions estimated for the last week of the current test and (2) the estimated Plot B emissions for the five-week period of the current test. In other words, the emissions for these 87 days were found by interpolating between emissions at the end points. This also assumes that the sludge applied in June was of the same composition as the sludge applied in these tests.

The use of these assumptions results in an estimated emission rate of 8.9 Mg/year or 43% of the applied volatile organic (see Appendix Q). (Of the 8.9 Mg, 6.4 Mg is emitted during the first five weeks after application and 2.5 Mg is emitted during the last twelve weeks.) Therefore, if emissions controls were 50% effective, a 4,500 kg/year reduction in volatile organics emissions might be obtained. An emissions control of 90% efficiency would result in an 8.0 Mg/year reduction in emissions.

It is difficult to determine whether the estimated annual emissions are based high or low, given the data at hand. There are several factors that could result in them being low. First, the measurements were made in the fall which is not the hottest season and there are some rainy months when sludge is not applied. Second, the night time emissions were assumed to be represented by the two pre-dawn sampling half-days which reflected dawn emission rates. Depending on how slowly the ground cools after sunset, the emission would be expected to be somewhat higher before dawn. Other factors may have led to high emission rate estimates. The flux chamber raises soil temperature and thus emissions. The tank bottoms probably have a lower VOC content, as may the "other waste." (But both types of waste only accounted for 12% of the total waste spread in 1984.)

It should also be pointed out that the percent of volatile organics, 4% of the oil present in the Chevron oily sludge, is lower than the amount of volatile organics (determined by purge and trap techniques) previously measured in liquid DAF and API separator sludges at a number of refineries (12).

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[1] Fortuitously, 116 days and 120 days are essentially the same length of time. Had the period between applications been significantly different from 116 days, the emissions estimate would have been truncated and expanded to include that whole period and then multiplied by the number of applications per year to obtain total annual emissions.

Volatile organic levels equivalent to 5 to 50% of the oil in the sludge were determined in this earlier study (12). Therefore, while this estimate is believed to be valid for this particular facility, high emissions rates and greater control benefits may be achievable at other facilities.

SECTION 9

PREDICTED AIR EMISSION RATE

Theoretical models have been proposed for predicting emissions from land treatment sites. The results of applying the most appropriate model to the Chevron land treatment area to estimate total volatile organics emission rates and individual specie emission rates are discussed below. A comparison of the measured and predicted emission rates is also presented.

DESCRIPTION OF MODELS

The Hartley Model (14) and the Thibodeaux-Hwang Model (15) have been proposed for predicting emissions of volatile compounds from land treatment operations. These two models are presented and briefly discussed below.

Hartley Model

The form of the Hartley land treatment model is presented in Table 33. This model is based on Fick's first law in which the rate of molecular diffusion is assumed to be proportional to the diffusion coefficient and to the saturation vapor concentration. In developing this model, Hartley assumed that the evaporation of a volatile compound from soil surfaces is related to the molecular diffusion coefficient of that compound in air. Under constant ambient conditions, Hartley found that the ratio of the evaporation or emission rate to the product of vapor pressure and molecular weight was reasonably constant in laboratory evaporation studies of several compounds of varying volatility. These compounds were pure liquids and solids, rather than multicomponent mixtures or solutions. Since the ratio was approximately constant, Hartley proposed that the evaporation rate of a reference compound could be used to predict the unknown evaporation rate of any other volatile chemical compound.

The Hartley model is simple to use and most of the required input parameters are readily available. The predicted vaporization rates have been verified in laboratory studies of pesticide evaporation from soil surfaces. The model has several deficiencies, however, when applied to typical land treatment operations. Some of these weaknesses are listed below:

- The model predicts a maximum emission rate from volatile compounds exposed to the atmosphere on the soil surface. It does not account for diminished rates due to soil permeation (below the surface) by the volatile material;

TABLE 33. HARTLEY MODEL FOR VOLATILE EMISSIONS FROM LAND TREATMENT OPERATIONS

Model: Hartley (14)
Disposal Method: Landtreatment
Type of Model: Predictive
Basis: Emission rates are estimated from evaporation rates (from liquid surfaces) of reference compounds.

Form:

$$E_a = \frac{E_b}{(1-RH)} \times \frac{P_a}{P_b} \frac{(M_a)^{\frac{1}{2}}}{(M_b)^{\frac{1}{2}}} \times \frac{W_a}{W} \qquad (14)$$

Symbol	Symbol/Parameter Definition	Source of Input Parameter
E_a	Flux (emission rate) of chemical compound in question, g/cm^2-sec	-
E_b	Flux of the reference compound (water is often used as the reference compound), g/cm^2-sec	Published data or direct measurement
P_a	Vapor pressure of the chemical compound in question, mm Hg	Published data or direct measurement
P_b	Vapor pressure of the reference compound, mm Hg	Published data or direct measurement
M_a	Molecular weight of the chemical compound in question, g/g-mole	Published data
M_b	Molecular weight of the reference compound, g/g-mole	Published data
RH	Relative humidity, fraction of saturation	Tabulated values or direct measurement
W_a/W	Weight fraction in applied waste of chemical compound in question	Direct measurement

- The volatile material is assumed to evaporate at the maximum rate until it has been exhausted; and
- The model is not readily extended to complex, multicomponent or multiphase mixtures.

The Hartley model was not used to predict emission rates in this study since it is inadequate for describing evaporation of volatile waste material that has permeated into the soil below the surface.

Thibodeaux-Hwang Model

A mathematical model for predicting atmospheric emissions of volatile chemical compounds from land treatment operations (including those of petroleum refineries) has been proposed by Thibodeaux and Hwang (15). This model is presented in Table 34. In the development of this model, the emission rate of a volatile chemical compound is assumed to be a function of:

- The evaporation rate of the compound from the interstitial soil surfaces; and
- The diffusion rate of the chemical compound through the air-filled pore spaces of the soil.

The emission rate is assumed to be controlled by the diffusion rate in the air pore space when the oil loading is relatively low and soil particles are small, as they are in this case.

At soil loadings substantially greater than typical pesticide loadings, the mathematical description of the emission process is extremely complex. Thibodeaux and Hwang were forced to make a significant number of simplifying assumptions to develop a usable mathematical expression. The resulting model is a simplified description of a very complex process. However, it is the most sophisticated model which has yet been published.

The Thibodeaux-Hwang model, as developed, applies strictly to single chemical compounds. The emissions of groups of classes of compounds have been estimated, however, by assuming a single set of component properties for the entire class. However, there is a considerable degree of uncertainty in the development of model parameters that are representative of the various classes. This uncertainty is very difficult to quantify.

The Thibodeaux-Hwang model requires a number of parameters in addition to the measured variables. These parameters include:

- D_{wi}, the effective diffusivity of species i in the oil;
- D_{ei}, the effective diffusivity of species i in air;
- H_c, Henry's law constant in concentration terms; and
- f, fraction of oil in film form.

TABLE 34. THIBODEAUX-HWANG MODEL FOR VOLATILE ORGANIC EMISSIONS FROM LAND TREATMENT OPERATIONS

Basis: Emission rate is controlled by diffusion rate of vapor through the air-filled pores of the land treated soil.

Form:

$$E_i = \frac{D_{ei}\ C_{ig}}{\left[h_s^2 + \dfrac{2\ D_{ei}\ t\ A\ (h_p - h_s) C_{ig}}{M_{io}} \right]^{1/2}} \qquad (15)$$

$$C_{ig} = \frac{H_c\ C_{io}}{1 + \dfrac{H_c\ D_{ei}\ Z_o}{D_{wi}\ A_s\ f(y)}} \qquad (16)$$

and

$$f(y) = (h_p^2 + h_p h_s - 2h_s^2)/6 \qquad (17)$$

Symbol	Symbol/Parameter Definition	Measured or Estimated Precision	Source of Input Parameter
A	surface area over which waste is applied, cm^2	± 2%	measured
A_s	interfacial area per unit volume of soil for the oily waste, cm^2/cm^3	-	calculated
C_{ig}	effective wet zone pore space concentration of component i, g/cm^3	-	calculated
C_{io}	concentration of component i in oil, g/cm^3	± 80-200%	measured
D_{ei}	effective diffusivity of component i in the air-filled soil pore spaces, cm^2/s	± 25%	published data; estimation

(Continued)

TABLE 34. (Continued)

d_p	soil clump diameter, cm	± 36%	average calculated from measurements
D_{wi}	effective diffusivity of compound i in the oil, cm^2/s	± 30%	published data; estimation
E_i	flux of component i from the soil surface, g/cm^2-sec	-	calculated
f(y)	$(h_p^2 + h_p h_s - 2h_s^2)/6$ accounts for the lengthening dry zone	-	calculated
H_c	Henry's Law constant in concentration form, cm^3 oil/cm^3 air	± 15%	published data
h_p	depth of soil contaminated or wetted with land treated waste, cm	± 10%	measured
h_s	depth of subsurface injection	± 10%	measured
M_{io}	initial mass of component i incorporated into the zone (h_p-h_s), g	± 5%	measured
t	time after application, sec		measured
y	height of wetted soil remaining after partial drying, cm	-	measured
w_f	weight fraction oil in film form in soil	-	calculated
Z_o	oil layer diffusion length, cm	-	calculated or estimated
f	fraction of oil in film form	-	estimated
p_p	soil clump density, g/cm^3	± 30%	measured or estimated
p_w	waste-oil density, g/cm^3	± 10%	measured or estimated

TOTAL VOC EMISSION RATES

The Thibodeaux-Hwang model can be used for land treatment facilities which are surface or subsurface applications. Although the testing at the Chevron El Segundo facility included both surface and subsurface applications, the tilling operations immediately after either application produce a condition that seems to be best described by the surface application model. This approach assumes that the sludge concentration in the soil is uniform immediately after application. Therefore, the modeling for this study is only for surface application, and only for one plot, since both plots are assumed to be the same for modeling purposes.

Model Inputs for the Chevron Facility

The parameters D_{wi}, D_{ei}, and H_c are presented in Tables 35, 36, and 37, respectively. Values for the diffusivities of organics in air and oil are calculated from recognized estimating techniques (16,17). Henry's law constants for hydrocarbons in an organic solvent were calculated using the equation below:

$$H_c = [(KC_gM_A)/p_w] \tag{18}$$

where: H_c = Henry's law constant in concentration form, cm^3 oil/cm^3 air
C_g = molar density of vapor ($1/2.24 \times 10^4$ g-mol/cm^3)
M_A = average molecular weight of the oil (assumed to be eicosane), g/g-mole
p_w = density of the oil, g/cm^3
K = vapor pressure equilibrium constant

The rationale for assuming the average molecular weight of the oil as equivalent to eicosane is discussed in Section 8.

Vapor pressures were obtained from the Antoine correlation using tabulated constants (18). The equilibrium constants were determined from the relationship below:

$$K_i = (p_i/p_T) \tag{19}$$

where: K_i = vapor-liquid equilibrium constant for component i
p_i = vapor pressure of pure component i, mm Hg
p_T = total pressure, mm Hg

Total atmospheric pressure was assumed to be 760 mm Hg. The properties of the compound classes were assumed to be an average of the properties of the major compounds of each class (as listed in Table 35) found in the sludge.

The mass fraction of oil in the film form can be estimated by Equation 20.

TABLE 35. DIFFUSIVITIES OF SELECTED COMPOUNDS IN OIL WASTE APPLIED TO LAND TREATMENT AREA, CHEVRON EL SEGUNDO

Compound	Molecular Volume cm^3/g-mole	Diffusivities in Oil[a] cm^2/sec
n-Heptane	163	5.33×10^{-5}
3-Methylheptane	185	4.95×10^{-5}
n-Nonane	207	4.62×10^{-5}
1-Octene	178	5.06×10^{-5}
B-Pinene	207	4.62×10^{-5}
Limonene	207	4.62×10^{-5}
Toluene	133	6.03×10^{-5}
m/p-Xylene	155	4.79×10^{-5}
o-Ethyltoluene	178	5.06×10^{-5}
Paraffins	--	4.96[b] $\times 10^{-5}$
Olefins	--	4.77[b] $\times 10^{-5}$
Aromatics	--	5.08[b] $\times 10^{-5}$
TNMHC	--	4.97[b] $\times 10^{-5}$

[a] Assumes oil is equivalent to n-eicosane.

[b] Diffusivities are assumed to be an average of the representative compound diffusivities in each compound class.

TABLE 36. EFFECTIVE DIFFUSIVITIES OF SELECTED COMPOUNDS IN AIR-FILLED PORE SPACES OF LAND TREATMENT SOIL

Compound/ Compound Group	Diffusivity in Air (D_i) @25°C, cm^2/sec	Diffusivity (D_{ei})[a] in Air @25°C cm^2/sec
n-Heptane	0.072	0.029
3-Methylheptane	0.066	0.026
n-Nonane	0.065	0.026
1-Octene	0.067	0.027
B-Pinene	0.059	0.023
Limonene	0.058	0.023
Toluene	0.079	0.031
p/m-Xylene	0.071	0.028
o-Ethyltoluene	0.063	0.025
Paraffins	0.067	0.027
Olefins	0.061	0.024
Aromatics	0.071	0.028
Total NMHC	0.065	0.027

[a] $D_{ei} = D_i \varepsilon^{4/3}$, where ε is the soil porosity and is equal to 0.50.

TABLE 37. VAPOR PRESSURES, EQUILIBRIUM CONSTANTS, AND HENRY'S LAW CONSTANTS FOR SELECTED COMPOUNDS IN OILY WASTE APPLIED TO LAND TREATMENT AREA, CHEVRON EL SEGUNDO

Compound or Class of Compound	Vapor Pressure @25°C mm Hg	Vapor-Liquid Equilibrium Constants K	Henry's Law Constant Concentration Form H_c
n-Heptane	45.7	0.0601	7.07×10^{-4}
3-Methylheptane	19.5	0.0257	3.02×10^{-4}
n-Nonane	4.3	0.0057	6.71×10^{-5}
1-Octene	17.4	0.0229	2.69×10^{-4}
B-Pinene	2.7	0.0036	4.23×10^{-5}
Limonene	3.0	0.0039	4.59×10^{-5}
Toluene	28.4	0.0374	4.40×10^{-4}
p/m-Xylene	8.3	0.0109	1.28×10^{-4}
o-Ethyltoluene	2.5	0.0033	3.88×10^{-5}
Paraffins	--	--	3.77[a] $\times 10^{-4}$
Olefins	--	--	1.19[a] $\times 10^{-4}$
Aromatics	--	--	2.03[a] $\times 10^{-4}$
Total NMHC	--	--	2.65[a] $\times 10^{-4}$

[a] Assumed to be an average of the H_c values of the representative compounds in each compound class.

$$W_f = \frac{0.5\ M_T}{h_p\ P_p A} \qquad (20)$$

where M_T is the total amount of waste application (g), and the rest of the terms are as defined in Table 34. The fraction of oil in the film form, according to the above equation, is approximately 5% for the application at the Chevron site. Since 95% of the oil is present in the lump form, all of the oil was assumed to be in this form for modeling purposes.

The concentrations of the selected compounds and compound classes in the applied sludge were determined from analyses of oily sludge samples taken shortly before application to the land treatment test plots. The initial amount of each species and compound class are shown in Table 38. Additional parameters included in the model are presented in Table 39. It should be noted that there are large uncertainties in many of these parameters, as noted in Table 34, as well as uncertainties in the assumptions used in developing the model.

Predicted Total VOC Emissions

The Thibodeaux-Hwang model (Equations 15 and 16) were used in calculating the emission rates at selected elapsed times from sludge application. The emission rates predicted by this model decline exponentially with time. Total or annual emission rates were not determined, since the model, as now formulated, will predict that all of the applied volatile material will be ultimately vaporized. However, before this total vaporization occurs, some biological degradation may have occurred, reducing NMHC emissions at some time. The level or amount of degradation is not currently known and is not included in the model.

The land treatment area was tilled regularly. The theoretical effect of this tilling is to mix the soil into a layer having a constant composition. The new composition is reduced by the amount of material which was vaporized between the previous and current tillings. The tilling may result in a temporary increase in the vapor emission rate. If the area is tilled after a period of time and this period is less than the life-time of species in either film or lump form, the remaining masses in the wet zone are uniformly redistributed in the soil layer. Thibodeaux and Hwang have estimated the mass loss of single species during each tilling cycle as follows (19):

$$M_{i\bar{t}} = 2At\ E_{i\bar{t}} \qquad (21)$$

where: $E_{i\bar{t}}$ (g/m^2-sec) is the flux rate of the species at $t = \bar{t}$. The remaining mass, $M_{io}-M_{i\bar{t}}$, is then used in the model equation to compute the flux rates after tilling. The tilling schedule for the Chevron El Segundo test is shown in Table 40.

TABLE 38. LOADING OF SELECTED COMPOUNDS AND COMPOUND GROUPS ON LAND TREATMENT AREA, CHEVRON EL SEGUNDO

Compound/ Compound Class	Total Amount Applied to Landtreatment Area[a] (M_{io}), grams
n-Heptane	1,620 ± 2,020[b]
3-Methylheptane	2,000 ± 2,460
n-Nonane	1,490 ± 3,020
1-Octene	465 ± 540
B-Pinene	2,240 ± 4,820
Limonene	1,140 ± 1,760
Toluene	4,350 ± 4,340
p/m-Xylene	3,930 ± 3,520
o-Ethyltoluene	1,820 ± 1,760
Paraffins	50,000 ± 95,000
Olefins	17,300 ± 20,100
Aromatics	40,300 ± 28,800
Total NMHC	111,400 ± 134,000

[a] Land treatment area is considered the test plot area of the surface application method.

[b] Two standard deviations (95% confidence interval)

TABLE 39. VALUES OF PARAMETERS USED IN THIBODEAUX-HWANG LAND TREATMENT MODEL

A = area of land treatment site[a], 423 ± 8 m^2

d_p = soil clump diameter, 0.038 ± 0.014 cm

hp = average depth of oil penetration, 25.4 ± 2.5 cm

M_T = total amount of sludge applied to land treatment area, 1.40 ± 0.15 x 10^7 g

M_a = molecular weight of the oil (assumed to be eicosane), 282 g-mole

p_w = average density of applied waste, 1.07 ± 0.1 g/cm^3

p_p = soil clump density, 2.50 ± 0.75 g/cm^3

ε = soil porosity, 0.50 ± 0.15

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[a] Land treatment site is considered the test plot area of the surface application method.

TABLE 40. TILLING SCHEDULE FOR CHEVRON LANDFARM - TEST STUDY

Date	Tilling Time	Hours from Start[a]	Activity
10-10-84	0950-1030	0	Apply waste and till
10-12-84	1224-1258	50.5	Till
10-15-84	0930-1100	120.5	Till and irrigate
10-16-84	1300-1400	147.5	Till
10-18-84	0800-0930	191	Till
10-19-84	1300-1430	220	Till
10-24-84	1222-1235	338.5	Till
10-26-84	1218-1233	386.5	Till
10-29-84	0815-0930	455	Till
10-30-84	0900-1100	480	Till and irrigate
10-31-84	1000-1100	504.5	Till
11-01-84	0900-1100	528	Till and irrigate
11-02-84	0900-1030	552	Till
11-05-84	1300-1430	628	Till and irrigate
11-09-84	1225-1245	722.5	Till
11-12-84	1047-1110	793	Till

[a] Rounded off to nearest 1/2 hour.

PREDICTED EMISSION RATES

The emission rates of the selected individual, as well as classes of, organic compounds were predicted using the Thibodeaux-Hwang land treatment model. The predicted emissions for the test period of 798 hours are summarized in Table 41. Two cases were assumed, with tilling and without tilling, and the emissions were determined for each case. In one case, with tilling, the tilling schedule followed by Chevron during the test period was included in the modeling. In the second case, without tilling, the emissions were calculated with the model under the assumption that no tilling occurred over the entire test period. (Note that not tilling would be expected to reduce emissions in most cases, but might also reduce the effectiveness of land treatment by depriving the microbes of oxygen.)

As shown in Table 41, the model predicts substantial emissions of most of the selected compounds/classes. In fact, for two of the no-tilling cases, the model predicts that all of the applied material will be emitted before the end of the test period. This occurs for two of the more volatile compounds, toluene and n-heptane. For all except these two compounds, the emissions predicted with tilling are greater than those predicted for the no-tilling cases. The difference in emissions between the two cases becomes more pronounced for those compounds emitting at lower rates, i.e., those compounds having lower volatilities.

The predicted emission rates of total volatile organics (TNMHC) which were calculated with and without tilling effects are shown graphically in Figure 72. The emission rates calculated for the no-tilling case are indicated by the dashed line. The predicted emission rates for the tilling case are represented by the solid lines. The measured emission rates are shown as squares, with vertical error bars representing the width of the 95% interval. The upper and lower series of dots represent the upper and lower confidence intervals for the predicted emission rates with tilling. The emission rate curves for toluene and heptane are truncated at the time that all of the applied compound has been volatilized.

Although the emission rate profile is significantly affected by the tilling episodes, the total emissions are somewhat less dramatically affected as shown in Table 41. As seen in the graph, the primary result of the tilling is high peaks of emission rates in the land treatment operation due to the tilling. In comparison to the no-tilling case, this results in higher emission rates in the periods which follow immediately after the initial application and the first several tilling episodes. Lower rates are seen, however, later on in the no-tilling case.

The broad width of the confidence intervals of the predicted emission rates precludes a statistically significant conclusion regarding the capability of the Thibodeaux-Hwang model in accurately predicting emission rates of TNMHC from land treatment sites.

TABLE 41. PREDICTED EMISSIONS OF SELECTED ORGANIC COMPOUNDS FROM LAND TREATMENT AREA

Compound/ Compound Class	Mass Applied, g	Predicted Mass Remaining at End of Test (798 hours), g		Predicted Mass Emitted During Test (798 hours), g		Predicted Emissions, % of Applied Material	
		With Tilling	Without Tilling	With Tilling	Without Tilling	With Tilling	Without Tilling
n-Heptane	1,620	6	0[a]	1,614	1,620[a]	99.6	100.0
3-Methylheptane	2,000	73	483	1,927	1,517	96.4	75.9
n-Nonane	1,490	355	957	1,135	533	76.2	35.8
1-Octene	465	21	126	444	339	95.5	72.9
B-Pinene	2,240	779	1,642	1,461	598	65.2	26.7
Limonene	1,140	373	823	767	317	58.8	27.8
Toluene	4,350	34	0[b]	4,316	4,350[b]	99.2	100.0
p/m-Xylene	3,930	481	1,915	3,449	2,015	87.8	51.3
o-Ethyltoluene	1,820	634	1,335	1,186	485	65.2	26.6
Paraffins	50,000	1,082	6,270	48,918	43,730	97.8	87.5
Olefins	17,300	2,691	9,384	14,609	7,916	84.4	45.8
Aromatics	40,300	2,705	14,285	37,595	26,015	93.3	64.6
TNMHC	111,400	5,179	29,715	106,221	81,685	95.4	73.3

[a] Model predicts all applied n-heptane emitted after 530 hours.

[b] Model predicts all applied toluene emitted after 690 hours.

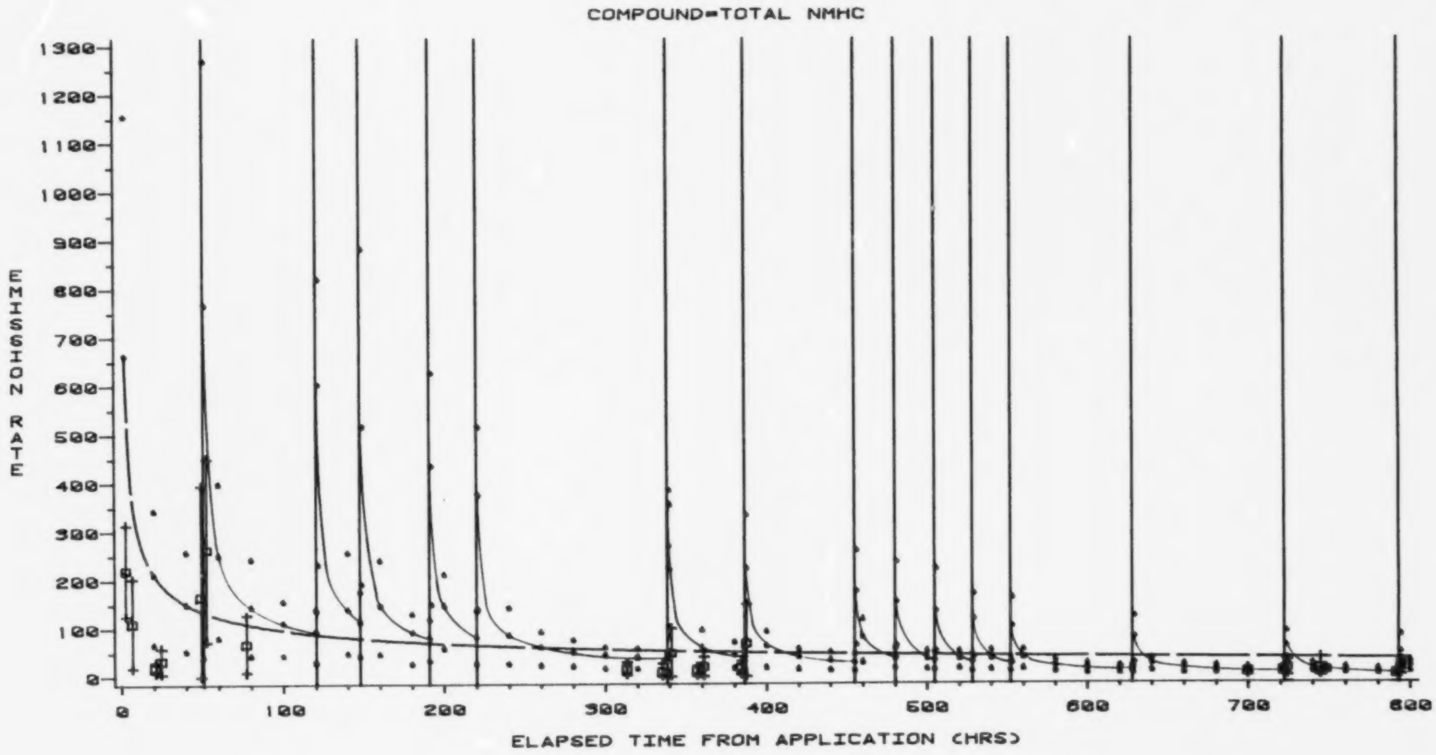

Figure 72. Emission rates of total NMHC from land treatment test plot with and without the effects of tilling.

COMPARISON OF MEASURED AND PREDICTED EMISSION RATES

The measured and predicted emission rates of the selected compounds and compound classes are both graphically presented in Figures 73 through 84. The rates are shown for both tilling and no-tilling cases. The measured rates are also included on the graphs. The confidence intervals are not shown on these figures, but they may be expected to be about the same magnitude as those shown for the TNMHC case (Figure 72). Thus, it is not possible to make any firm conclusions regarding the accuracy of the model in predicting emission rates. However, a comparison of the predicted rates to the measured rates shows a distinct trend, i.e., the mean predicted rates are generally considerably higher than the measured rates for all the selected compounds and compound classes. The predicted and estimated (from measurements) total emissions for the test period are summarized in Table 42. In all but one case (n-nonane, Plot C), the predicted emissions with tilling were greater than the estimated emissions from Plots A and C.

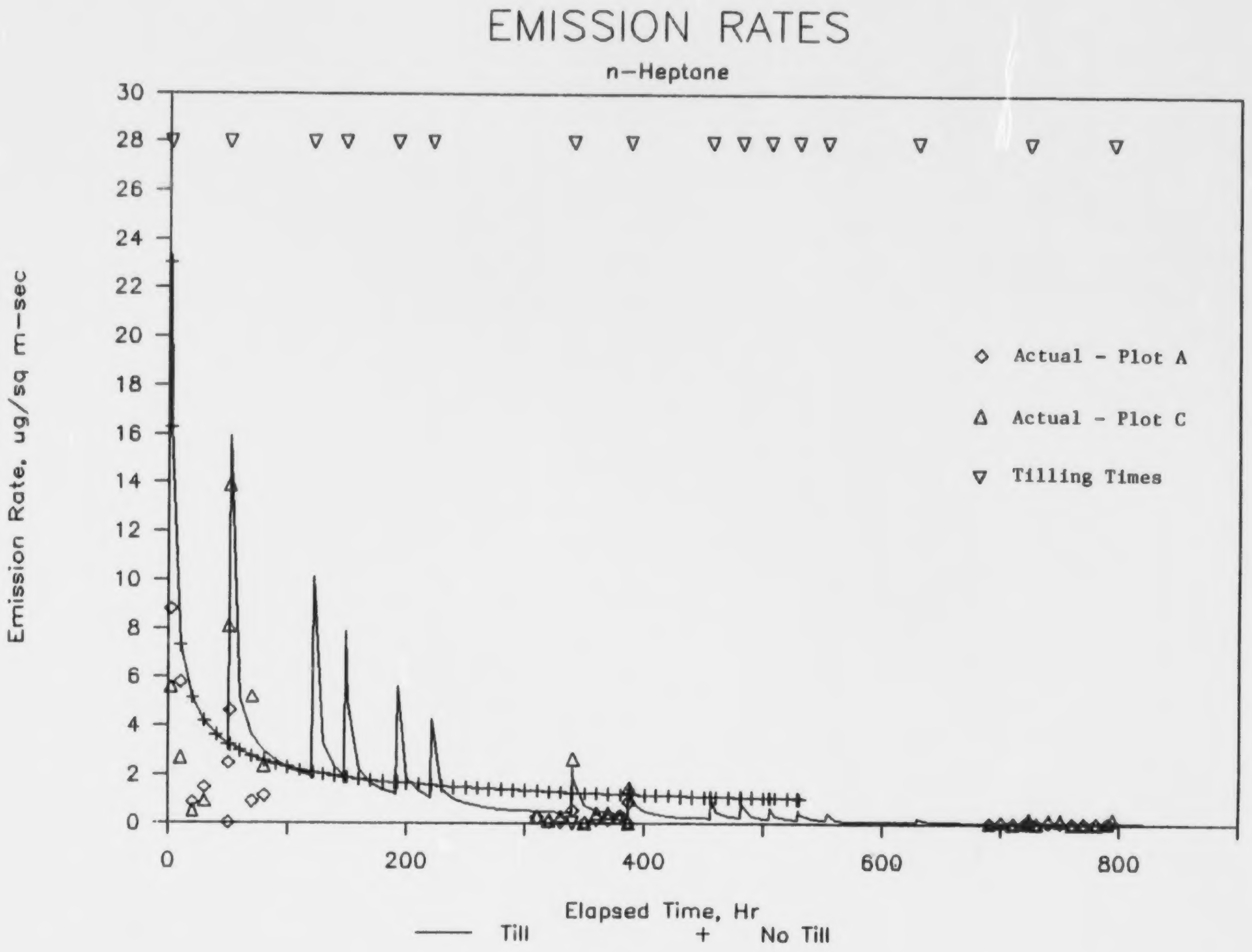

Figure 73. Predicted emission rates of n-heptane from land treatment test plot with and without the effects of tilling.

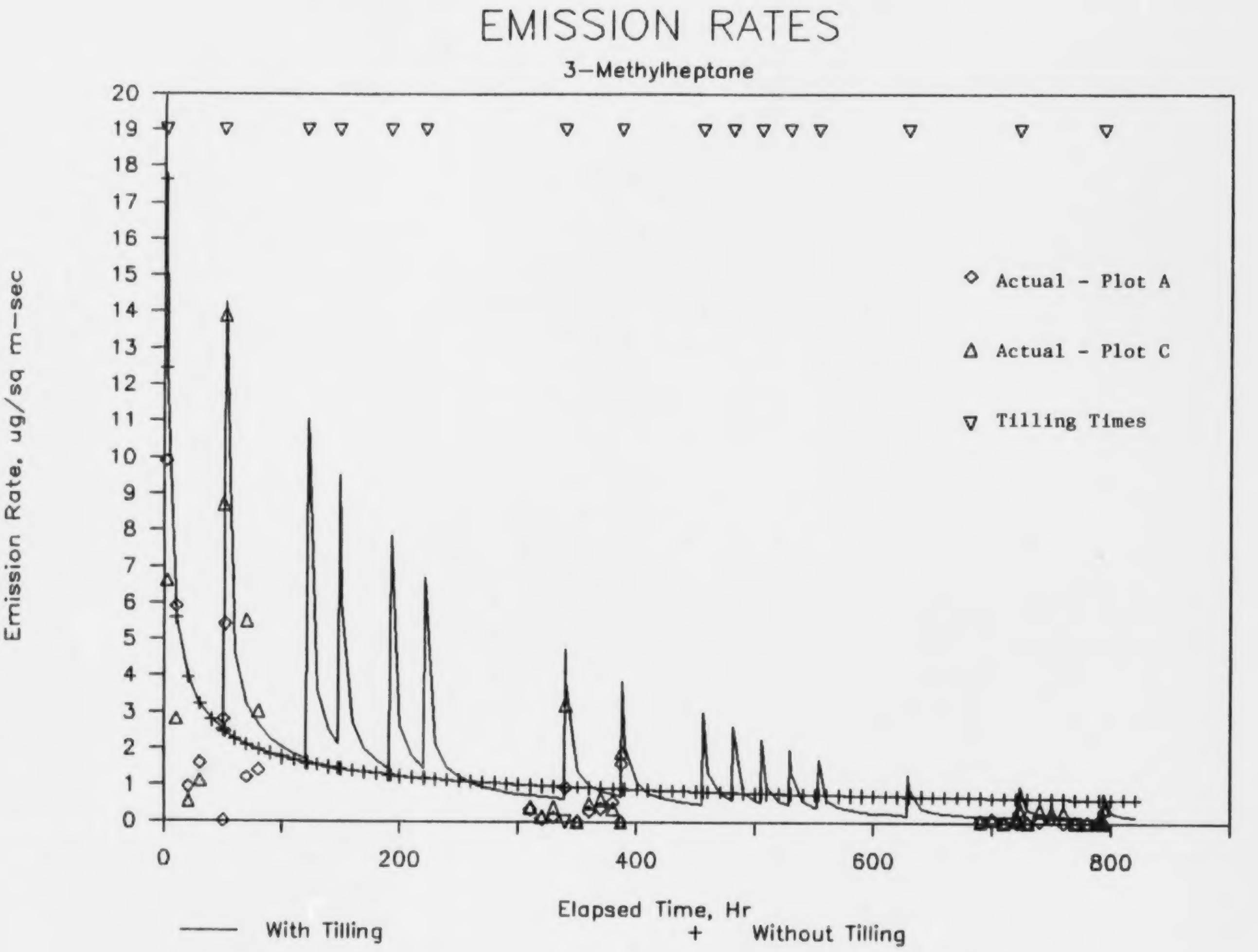

Figure 74. Predicted emission rates of 3-methylheptane from land treatment test plot with and without the effects of tilling.

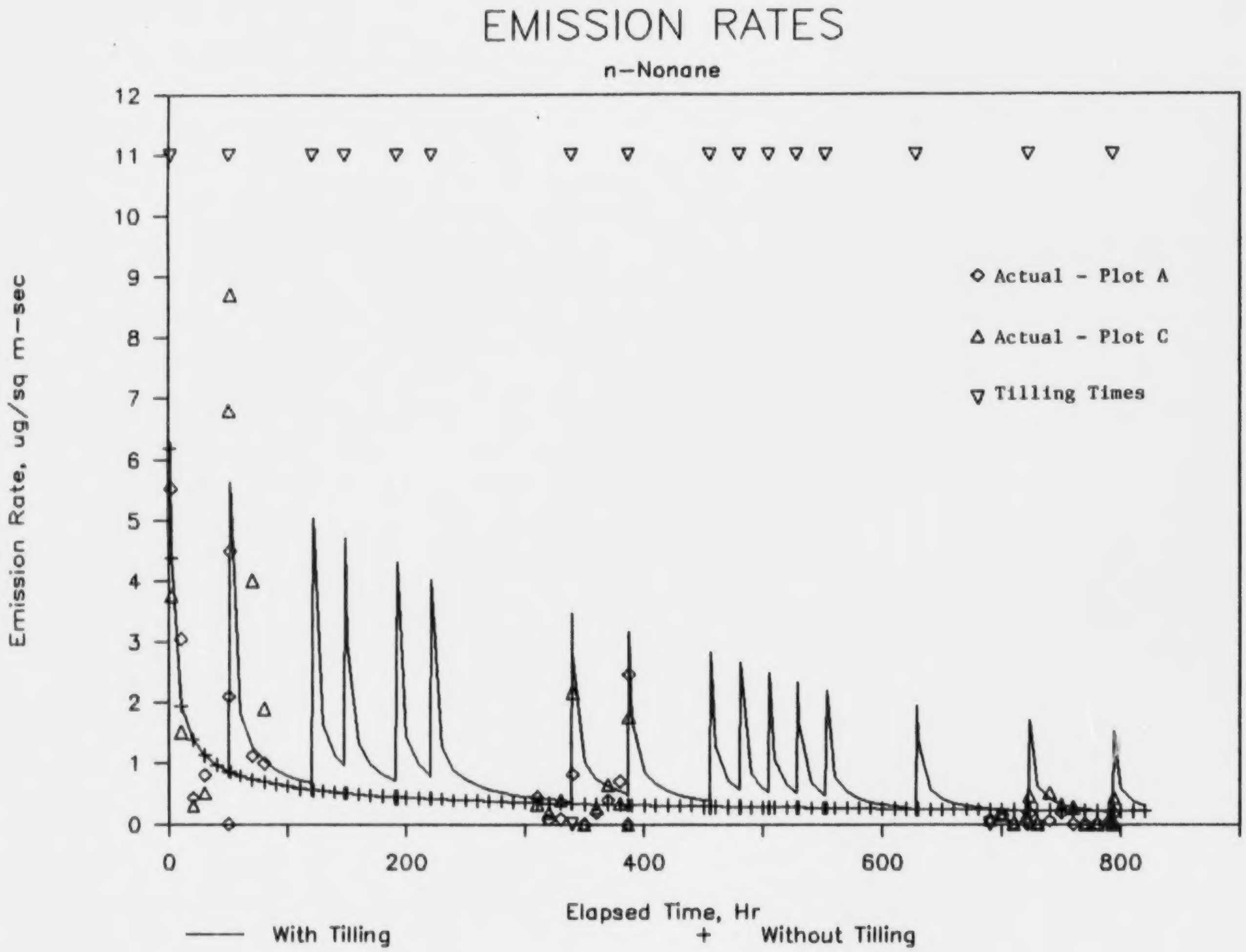

Figure 75. Predicted emission rates of n-nonane from land treatment test plot with and without the effects of tilling.

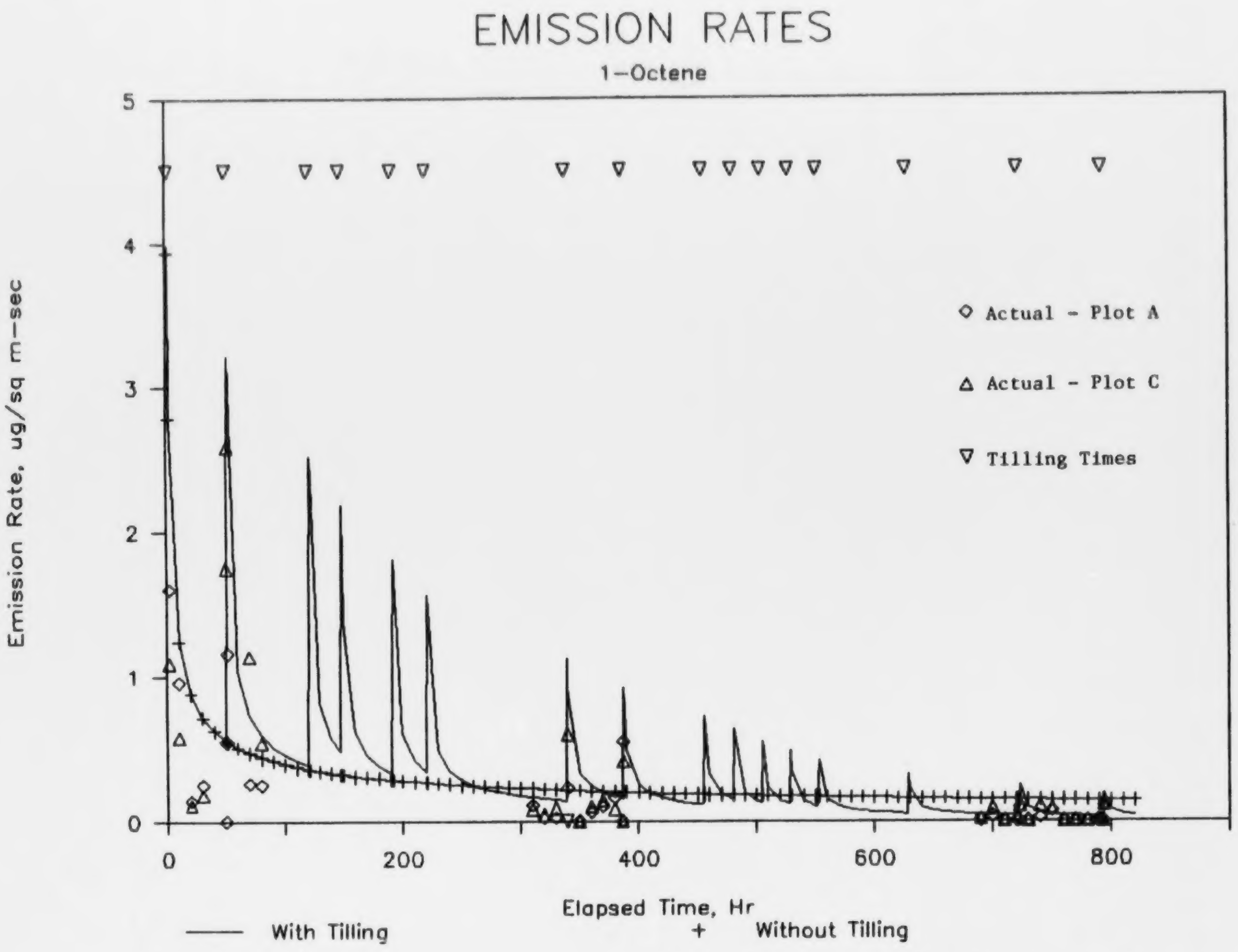

Figure 76. Predicted emission rates of 1-octene from land treatment test plot with and without the effects of tilling.

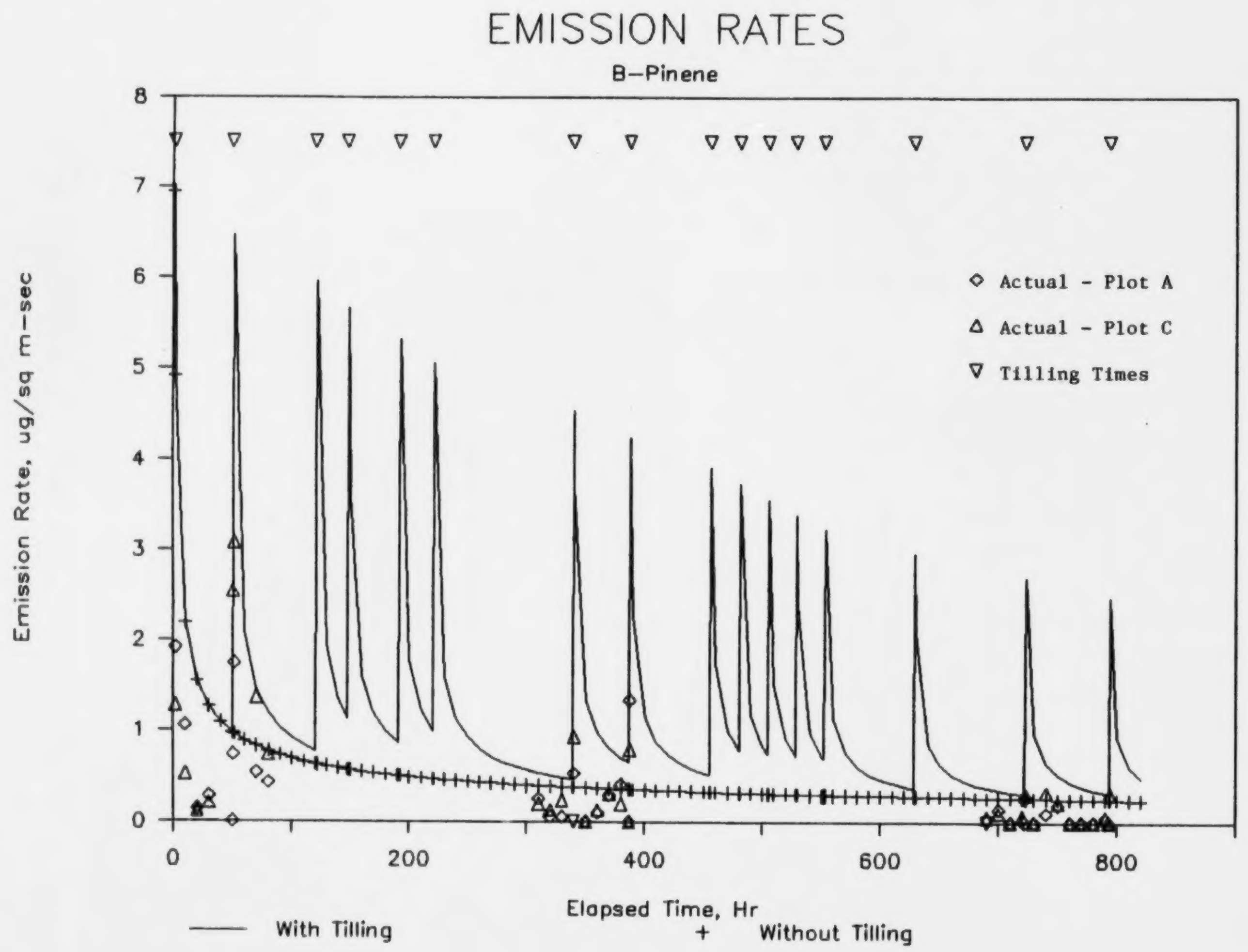

Figure 77. Predicted emission rates of β-pinene from land treatment test plot with and without the effects of tilling.

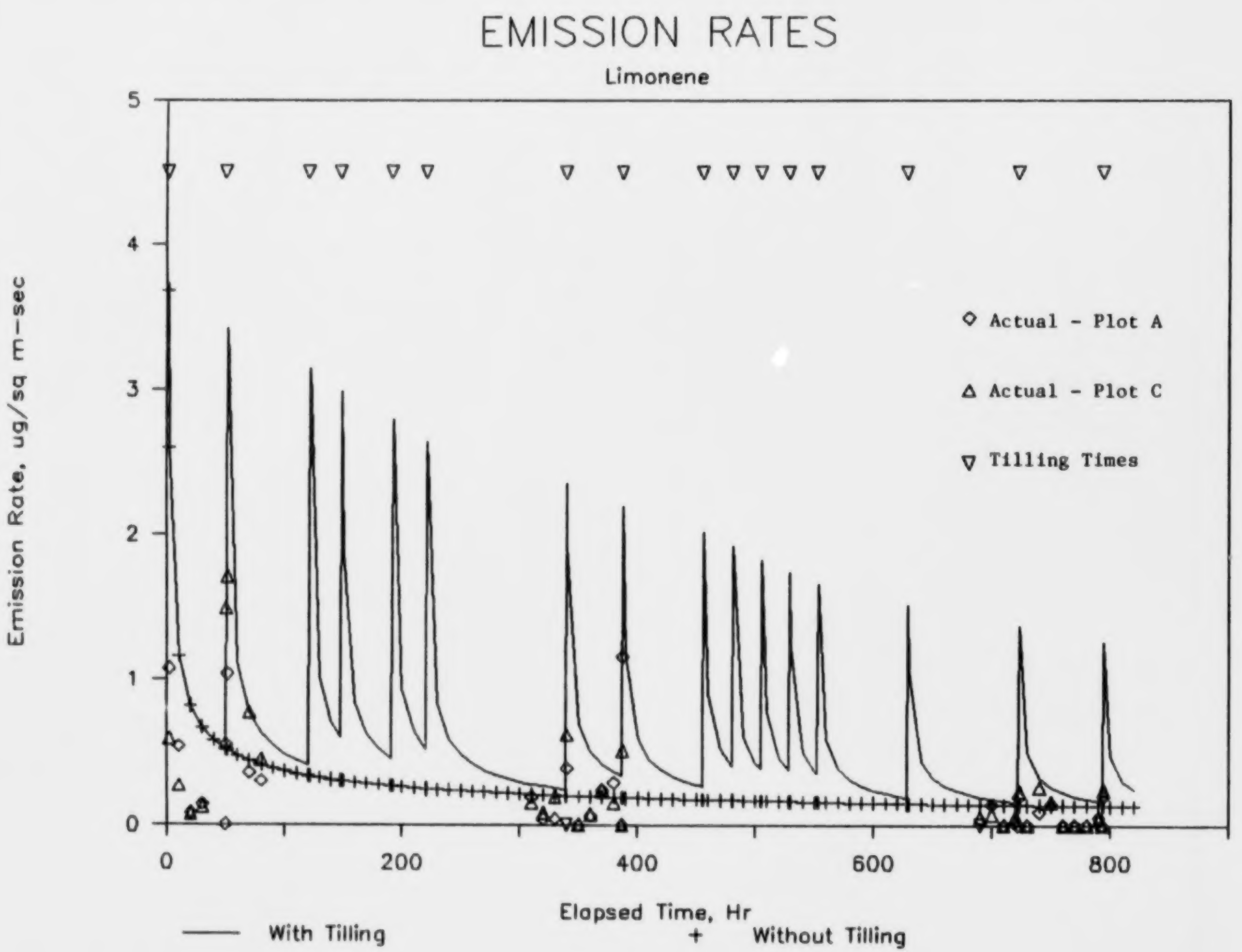

Figure 78. Predicted emission rates of limonene from land treatment test plot with and without the effects of tilling.

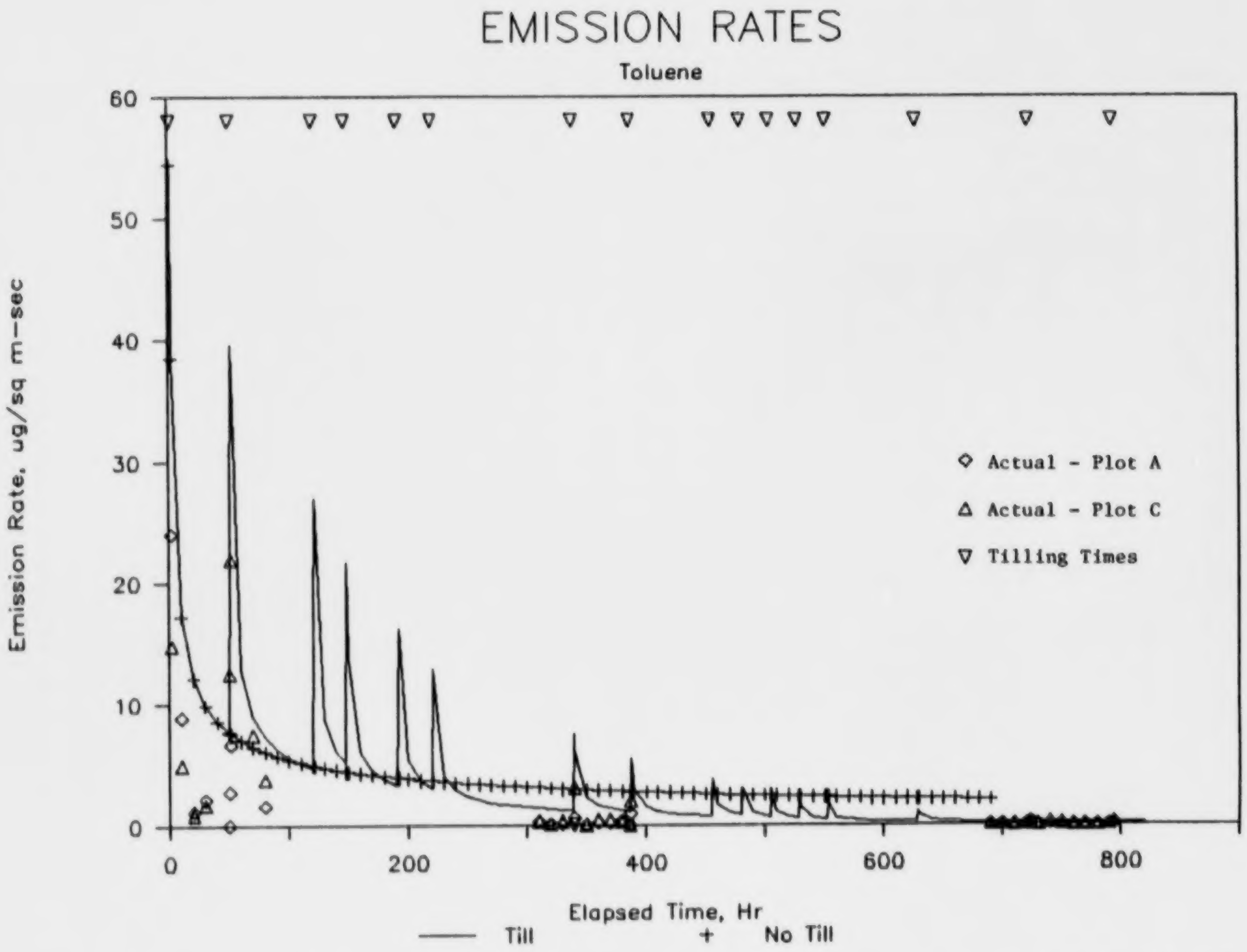

Figure 79. Predicted emission rates of toluene from land treatment test plot with and without the effects of tilling.

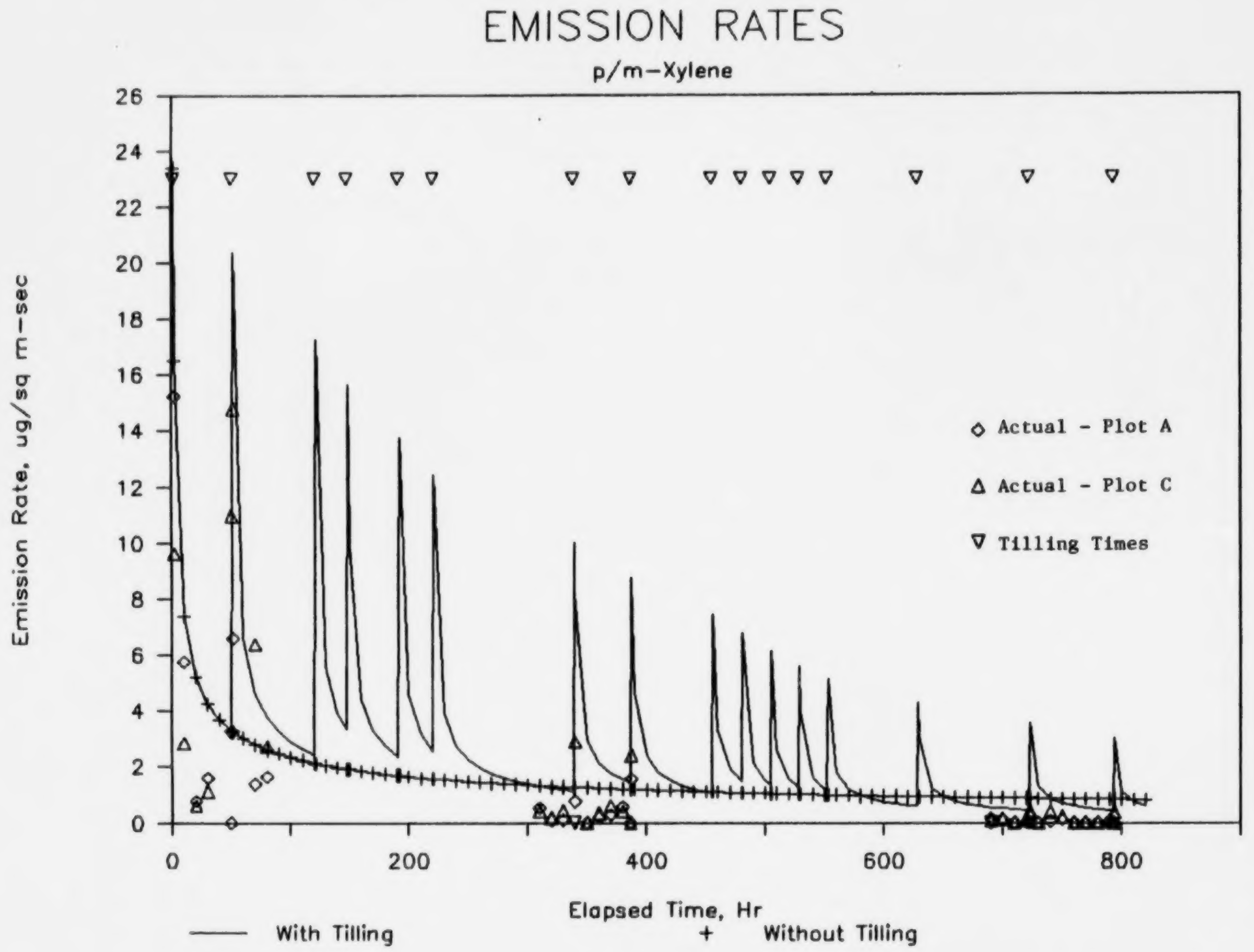

Figure 80. Predicted emission rates of p/m-xylene from land treatment test plot with and without the effects of tilling.

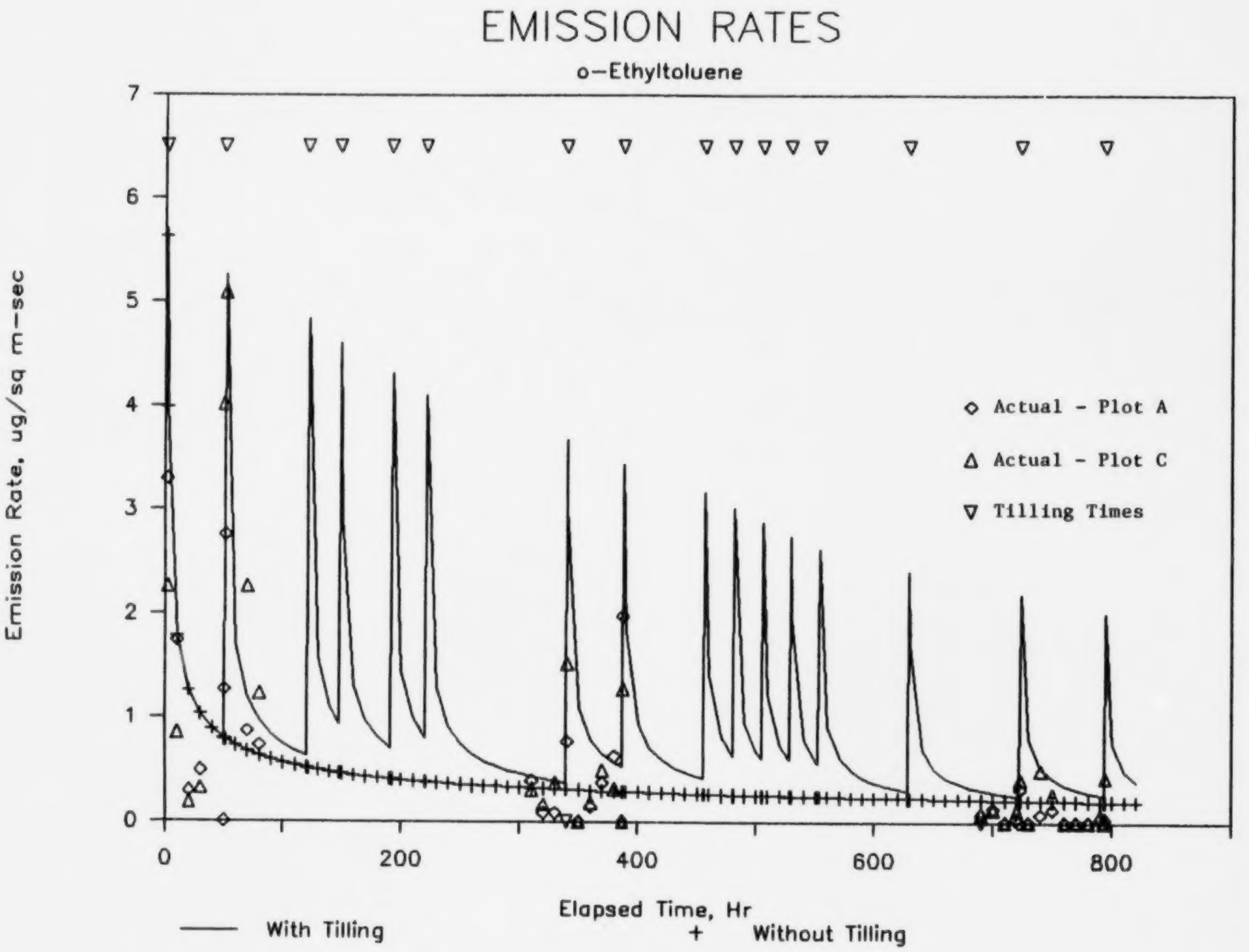

Figure 81. Predicted emission rates of o-ethyltoluene from land treatment test plot with and without the effects of tilling.

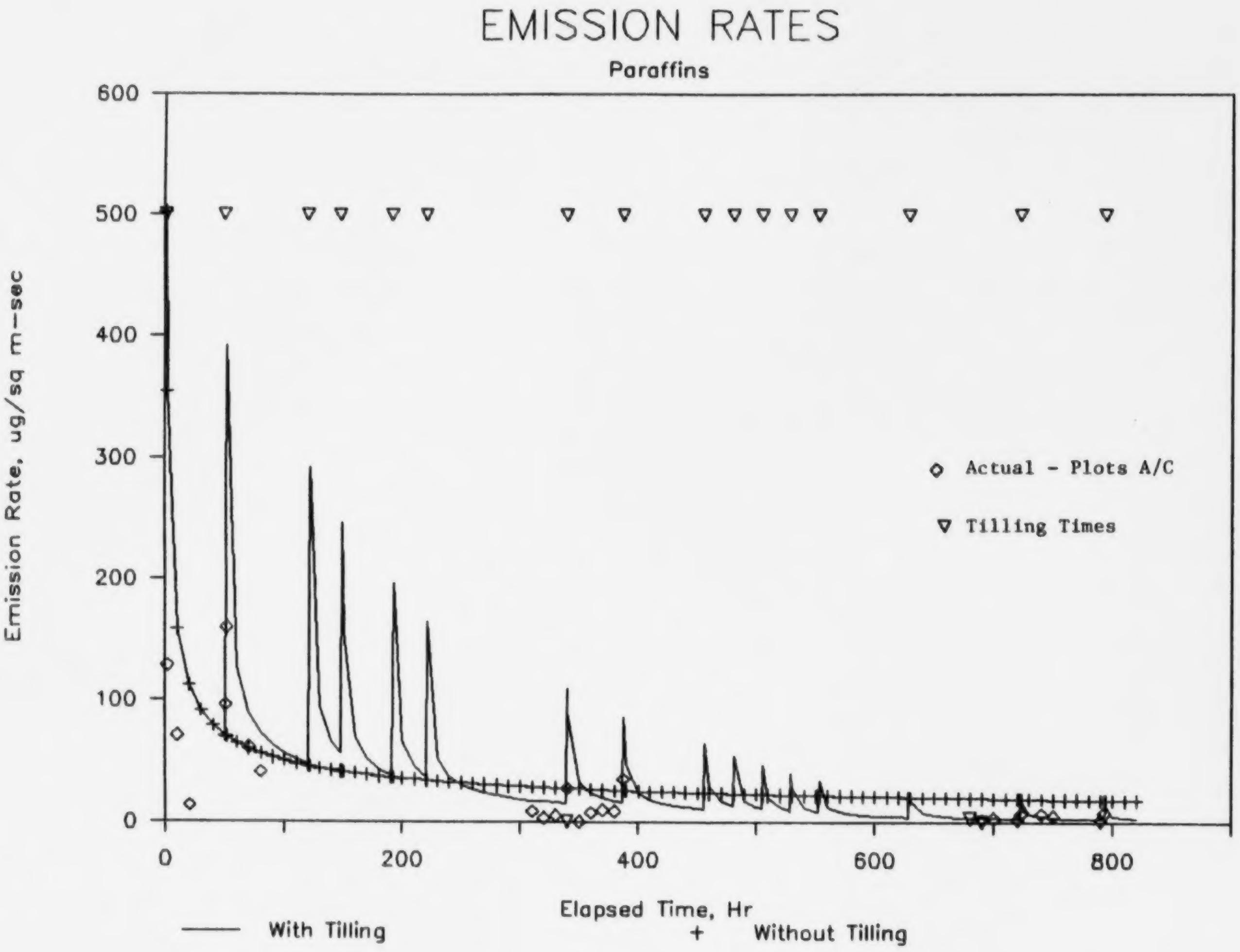

Figure 82. Predicted emission rates of n-paraffins from land treatment test plot with and without the effects of tilling.

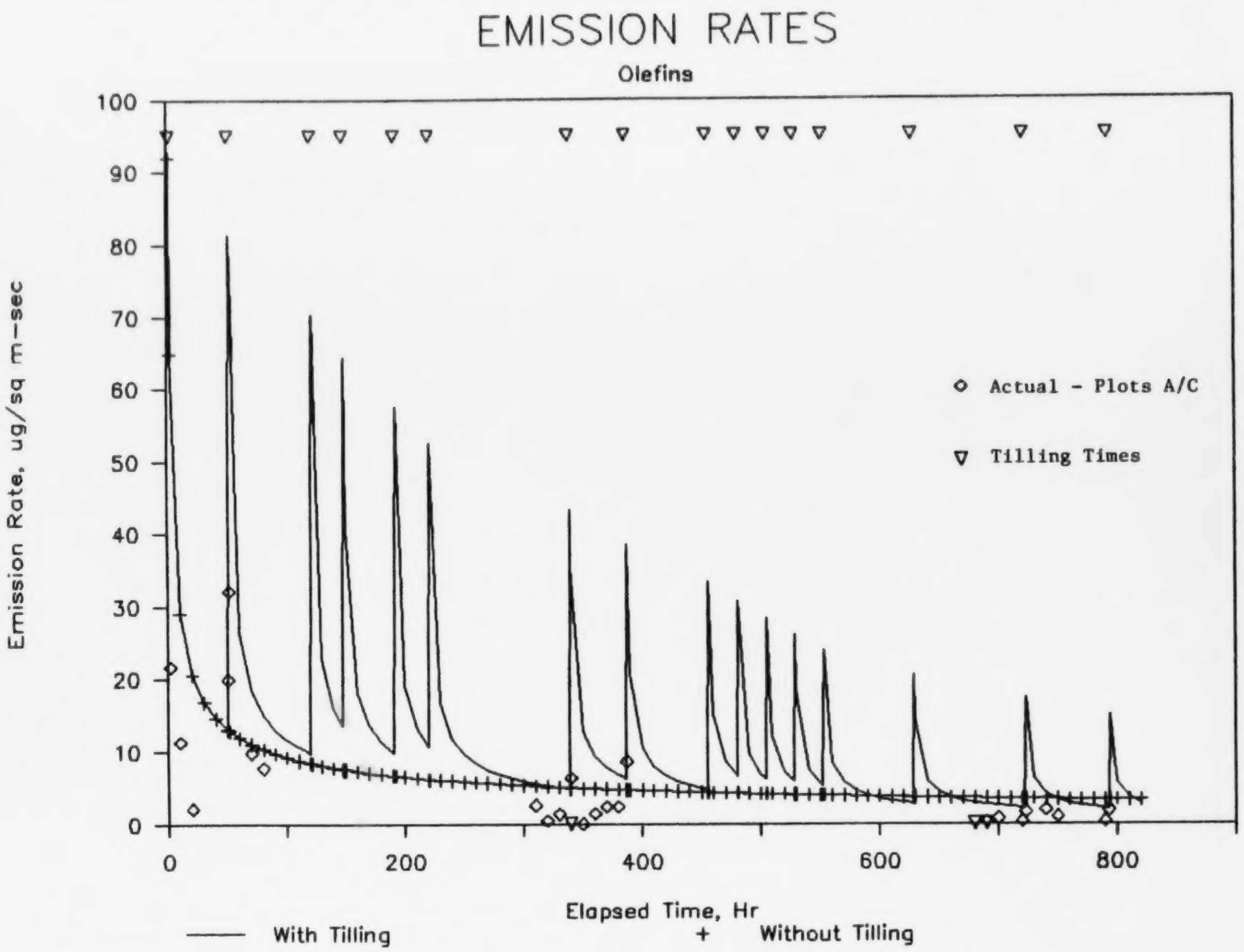

Figure 83. Predicted emission rates of olefins from land treatment test plot with and without the effects of tilling.

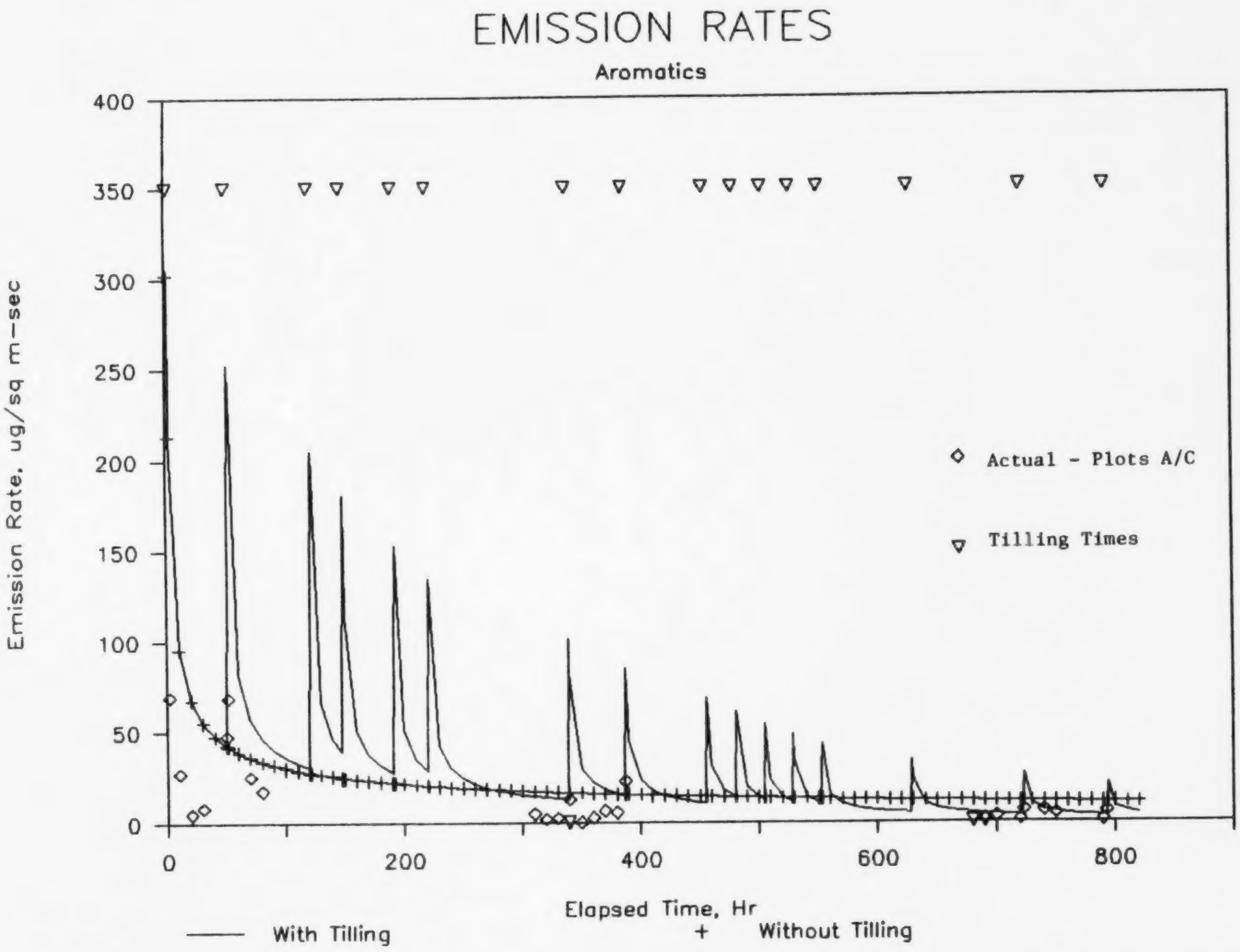

Figure 84. Predicted emission rates of aromatics from land treatment test plot with and without the effects of tilling.

TABLE 42. PREDICTED AND ESTIMATED EMISSIONS FROM LAND TREATMENT TEST PLOTS

Compound/ Compound Class	Predicted Total Emissions[a], g		Total Estimated Emissions[b], g	
	With Tilling	Without Tilling	Plot A (Surface)	Plot C (Subsurface)
n-Heptane	1,614	1,620	977	1,520
3-Methylheptane	1,927	1,517	1,050	1,550
n-Nonane	1,135	533	838	1,180
1-Octene	444	339	233	340
B-Pinene	1,461	598	374	474
Limonene	767	317	253	291
Toluene	4,316	4,350	1,620	2,430
p/m-Xylene	3,449	2,015	1,160	1,890
o-Ethyltoluene	1,186	485	582	758
Total VOC	106,221	81,685	33,300	39,000

[a] Using Thibodeaux-Hwang model.

[b] From field measurement results.

SECTION 10

DATA QUALITY

The test approach used during this project to measure volatile organics emission rates from Chevron's land treatment facility incorporated a comprehensive quality assurance/quality control (QA/QC) program as an integral part of the overall sampling and analytical efforts. The QA/QC program was designed, in part, to ensure that the emission rate data collected during the test program were complete, representative, and comparable to other similar data. It was also designed to control measurement data quality within prescribed limits of acceptability, and to ensure that the resulting data were of known quality with respect to precision and accuracy.

This section presents an assessment of the quality of measurement data collected during this test program. This assessment is based upon QC data and provides estimates of the uncertainty associated with the measurement data. In the interest of brevity, topics previously addressed in the QAPP (20) have been omitted here. These include a discussion of the objectives of the QA/QC effort and the general approach used in achieving these objectives, methods used in quantitating data quality, and definitions and explanation of QA/QC and statistical terminology.

The discussion is divided into three parts: summary and conclusion, onsite analyses, and off-site analyses.

CONCLUSIONS AND SUMMARY

The primary emphasis of this program was to measure pollutant concentrations in gas samples. The QA/QC program was designed to assess the accuracy and precision of these analyses. In addition, the QA/QC program addressed the data quality of the other sampling and analysis techniques. The QA objectives and the observed results are summarized in Table 43. The QA/QC data indicate that the data collected in this program were of acceptable quality.

ON-SITE ANALYSES

A Byron Model 401 THC analyzer was used to analyze syringe samples collected at the exit lines of the flux chambers. Samples were analyzed for total hydrocarbons (THC), carbon dioxide (CO_2), and methane (CH_4). At the start of the test program, three mixed gas standards were introduced to the analyzer to establish instrument linearity for each species. The THC linearity was rechecked at the start and finish of each subsequent week of sampling. All multipoint linearity checks exceeded the established acceptance criteria of $r \geq 0.995$ except for CO_2 which was slightly outside that range at

TABLE 43. SUMMARY OF QUALITY ASSURANCE OBJECTIVES AND RESULTS

		Objective			Results		
Measurement Parameter	Method	Precision[a]	Accuracy[b]	Data Capture[c]	Precision[a]	Accuracy[b]	Capture[c]
Pollution concentration (control inlet/outlet)	1) Canister sample, GC/FID-PID-HECD analysis	±30%	±50%	90%	±14.1%	±4.0-18.3%	100%
	2) Real-time analysis using THC analyzer (stationary) a) THC	±20%	±20%	90%	±22.8%[e]	±1.6%	65%[e]
	b) CO_2	±20%	±20%	90%	±9.8%[e]	±6.8%	65%[e]
Concentration of pollutant in liquids and slurries	Grab sample, GC/FID-PID HECD analysis (purge and cryotrap)	±30%	±100%	90%	±67.3%	±9.1-141%[d]	100%

[a] Coefficient of variation (relative standard deviation) for replicate determinations.

[b] Error for a single measurement, based upon daily quantitative standard results, expressed as a percentage of the measured value.

[c] Valid data percentage of total tests conducted.

[d] Only methylene chloride detection by PID/FID exceeded objective.

[e] Data for 10/26 through 11/10 is not included, therefore data capture is only 65%.

0.9935. Three additional quality control checks were performed daily. These tests are summarized in Table 44. A single point calibration check was normally performed at the beginning and end of each working day. An analytical blank was performed each morning and a system blank was obtained daily by setting the flux chambers over a teflon surface and sampling.

Over the course of the program, 80 duplicate analyses were performed and 17 duplicate syringe samples were collected and analyzed. Precision estimates based on these data are presented in Table 45. The individual analyses are listed in Appendix D. As previously discussed, the Byron data for 10/26, 11/08, 11/09, and 11/10 are unacceptable due to instrument problems. The sampling plus analytical variability for these days was ±61.9% for THC and ±81.0% for CO_2, compared to ±14.5% for THC and ±4.5% for CO_2 for the remainder of the data.

OFF-SITE ANALYSES

The off-site analyses involved GC analysis and various tests performed on the soil samples collected. This QC discussion is limited to the GC, % oil, water and solids, and oil and grease analyses; no quality control tests were performed for the physical testing of the soil samples.

Gas Chromatography Analysis

The samples analyzed by GC included gas canister samples collected from the exit lines of the flux chambers, integrated ambient air samples, the sludge applied to the landfarm, and the wastewater applied to the landfarm. All analyses were performed on a Varian 3700 gas chromatography system.

The Varian system was outfitted with three types of detectors: flame-ionization detector (FID), photo-ionization detector (PID), and a Hall electrolytic conductivity detector (HECD). The results of the quality control checks for the FID and PID detectors are summarized in Tables 46 through 48 and for the HECD in Tables 49 through 51. The QC checks performed are described below.

For the FID/PID, a 12-component standard was analyzed 16 times during the program to check for correct species identification. Each component was correctly identified on each check except for ethane and n-hexane which normally had their retention times somewhat shifted. During each day of analysis, single point propane and hexane calibration standards were run. These values were always well within the acceptance criteria of ±20%. Also, a daily blank was analyzed for that type of sample(s) being analyzed on that day. These values were generally acceptable and on those occasions where the gas blanks exceeded 10 ppbv-C, one or two contaminant peaks were responsible and were subtracted from subsequent analyses performed on that date. A 14-component EPA QC sample for volatiles was analyzed several times and the average percent recovery for 13 of the 14 components fell within the ±50% criteria.

TABLE 44. SUMMARY OF QUALITY CONTROL CHECKS FOR BYRON 401 ANALYSES

QC Check	Units	THC		CO_2		CH_4	
		Avg. Value	Range	Avg. Value	Range	Avg. Value	Range
Multipoint linearity check	Correlation coefficient	1.0000	1.000-1.000	0.9935	--[a]	0.9981	--[a]
Single point calibration check	% Difference between measured and true value	±1.59	-3.70-5.56	±6.83	-11.3-5.66	±3.32	-6.07-1.27
Analytical blank	ppmv-C	1.4	0-9	4.1	0-21	0.5	0-9
System blank	ppmv-C	2.5	0-8	65	3-253	0	0-1

[a] One multipoint linearity check performed.

TABLE 45. PRECISION ESTIMATES FOR BYRON SAMPLE RESULTS

Gas Species	Data Set	Mean Concentration (ppm)	Sampling Plus Analytical[a] (CV, %)	Analytical[b] (CV, %)
THC	Accepted data[c]	130	22.8	14.5
	All data	--	25.9	25.9
	Excluded data only	8.2	61.9	61.9
CO_2	Accepted data[c]	200	9.8	4.5
	All data	--	38.9	38.9
	Excluded data only	100	81.0	81.0

[a] Estimate of total variability in sampling/analytical process, based on results for duplicate samples.

[b] Estimate of analytical variability, independent of sampling variability, based on results for duplicate analyses.

[c] Data for 10/28 through 11/10 excluded.

TABLE 46. SUMMARY OF SPECIES IDENTIFICATION STANDARD FOR FID/PID

Date	Number of Compounds	Number of Correct Identifications
10-15-84	12	9
10-17-84	12	10
10-18-84	12	10
10-19-84	12	10
10-22-84	12	9
10-26-84	12	11
10-30-84	12	9
11-08-84	12	10
11-10-84	12	10
11-11-84	12	10
11-12-84	12	11
11-16-84	12	12
11-17-84	12	10
11-18-84	12	11
11-19-84	12	11
11-20-84	12	11

Standards contained: ethane, propane, 1-butene, *n*-butane, 1-hexene, *n*-hexane, ethyl benzene, *n*-octane, propyl benzene, *n*-decane, benzene, toluene

TABLE 47. SUMMARY OF DAILY QC CHECKS FOR FID/PID

QC Check	Units	Average Value	Relative Standard Deviation	Range	Number of Analyses
Quantitative Standard					
Propane	|% Error|	4.21	61%	-9.2-1.63	21
Hexane	|% Error|	4.00	58%	-7.7-8.0	21
Blank					
Gas	ppbv-C	16.6	25%	4.42-53.0	18
Water	ppbv-C	37.6	-	-	1
Water and Tetraglyme	ppbv-C	73.0	2.4%	71.8-74.2	2

TABLE 48. SUMMARY OF ANALYSIS OF EPA QC SAMPLE FOR VOLATILES FOR PID/FID

Compound	Average % Recovery[a]	Relative Standard Deviation	Range
Benzene	76.4	10.1%	68.6-84.1
Toluene	83.2	9.00%	74.7-88.7
Ethylbenzene	81.4	12.2%	71.9-91.7
o-xylene	87.0	7.55%	82.4-91.7
m-xylene or p-xylene	88.2	10.6%	83.2-93.3

[a] 3 analyses performed.

TABLE 49. SUMMARY OF DAILY QUANTITATIVE STANDARD FOR HECD

Compound	Average |% Error|	Relative Standard Deviation	Range	Number of Analyses
Chloromethane	14.3	170%	-28.2-95.8	15
Vinyl chloride	11.4	88%	-34.2-14.1	15
Dichlorodifluoromethane	9.1	95%	-27.8-13.8	15
Fluorotrichloromethane	10.2	95%	-28.3-15.4	15
1,1-Dichloroethylene	9.2	95%	-25.6-24.0	15
Methylene chloride	12.0	79%	-20.0-30.0	15
t-1,2-Dichloroethene	8.7	87%	-27.7-18.4	15
1,1-Dichloroethane	10.0	80%	-23.7-23.8	15
Chloroform	11.2	90%	-19.5-30.3	15
1,2-Dichloroethane	10.2	69%	-25.8-18.4	15
1,1,1-Trichloroethane	7.4	100%	-26.7-15.4	15
Carbon tetrachloride	6.6	110%	-28.4-15.8	15
1,2-Dichloropropane	18.3	43%	-19.7-28.9	15
Trichloroethylene	10.5	97%	-24-30.6	15
1,1,2-Trichloroethane	18.0	81%	-8.9-50.2	15
Tetrachloroethylene	9.4	77%	-16.6-24.7	15
Chlorobenzene	17.3	83%	-5.5-49.5	15

TABLE 50. SUMMARY OF DAILY BLANK SAMPLE ANALYSIS FOR HECD

Blank Type	Number of Analyses	Relative Standard Deviation	Average Value (ppbv-C)	Range
Gas	18	115%	8.0	0.00-32.1
Water	1	--	0.161	--
Water+Tetraglyme	2	90%	2.3	0.81-3.7

TABLE 51. SUMMARY OF ANALYSIS OF EPA QC SAMPLE FOR VOLATILES FOR HECD

Compound	Average % Recovery[a]	Relative Standard Deviation	Range
Methylene chloride	96.7	19.6%	70.0-115
1,1-Dichloroethane	86.7	31.1%	70.0-126
trans-1,2-Dichloroethylene	96.6	14.1%	86.5-117
1,2-Dichloroethane	134	2.99%	131-140
Carbon tetrachloride	102	4.58%	97.5-108
Trichloroethene	104	4.85%	98.2-110
Dibromochloromethane	138	5.49%	129-146
1,1,2,2-Tetrachloroethane	132	22.3%	113-175
Chlorobenzene	190	4.06%	181-197
1,2-Dichloropropane	158	7.96%	110-250

[a] 4 analyses performed

For the HECD, a 17-component quantitative standard was analyzed daily. All components had an average percent error of less than 20%. Blanks were run daily and all blanks were acceptable. A 10-component EPA QC sample for volatiles was analyzed four times during the project and each analysis was within ±50% for seven of the 10 components.

Selected samples were collected and/or analyzed in duplicate to provide precision information. These data are summarized in Table 52. Precision calculations based on these data are presented in Table 53. Results of duplicate analyses of sludge samples were given in Table 7 and discussed in Section 6.

Gas Chromatography/Mass Spectrometry (GC/MS)

The gas canister data were further checked by submitting four samples for GC/MS qualitative analysis. This was done to verify the compound identifications produced by the Varian GC system. The results of the GC/MS analyses are presented in Tables 54 through 57. The GC/MS instrument used was out of compliance (i.e., not able to meet QC objectives) during the time of these analyses. The GC/MS results are included for the sake of completeness, but the validity of this verification is subject to doubt. However, the data quality of the GC results is still acceptable based upon the other quality control tests performed.

Soil Oil and Grease Analyses

The oil and grease analyses for soil samples were performed over six days of testing. Each day a blank was run and a QC standard was analyzed. The blanks consisted of the tetrahydrofuran solvent used in the test procedure and the QC standard was a vegetable oil. Duplicate samples were analyzed on two occasions. The results of these tests are given in Table 58. The only unacceptable datum was the QC standard for one analysis day. The remaining QC standards were well within the 85-115% recovery criteria, the duplicate analyses were each within 1.1% of each other, and the blanks were never above 5 mg/g.

% Solids, Water, and Oil

The % solids, water, and oil in the sludge samples were determined using a method provided by Chevron. Results of replicate samples and analysis are given in Table 59. The results from 2-04-85 are considered suspect due to the probability that non-representative sample aliquots were used. This was the result of extracting the samples from small, VOA vial containers and insufficient mixing time. Subsequent analyses were performed using larger sample containers and longer mixing times. These results show excellent internal consistency with the exception of one % water determination.

Selected samples were spiked with vegetable oil to increase their oil content nominally by 15 and 30 percent. The vegetable oil was assumed to have no solids or water present. It was therefore possible to calculate the

TABLE 52. RESULTS OF DUPLICATE SAMPLES AND ANALYSIS OF GAS CANISTER SAMPLES

FIELD SAMPLE ID	SAMPLING LOCATION	SAMPLING DATE	SAMPLING TIME	PARAFFIN ug/m3	OLEFINS ug/m3	TOTAL AROMATICS ug/m3	TOTAL HALO-HC ug/m3	TOTAL OXYG-HC ug/m3	UNIDENTIF VOC ug/m3	TOTAL NMHC ug/m3
C044	C15	10-10-84	1150	161900	21610	64640	368	1565	0	248500
C044D	C15	10-10-84	1150	227600	31600	105700	58	1156	752	365700
C070	A07	10-10-84	1545	277200	46870	101400	108	892	594	426100
C071	A07	10-10-84	1545	238500	38230	93840	85	2960	356	371000
C100	A19	10-11-84	812	15110	1397	5195	156	246	269	22130
C100B	A19	10-11-84	812	16850	1973	5440	15	484	16	24300
C100D	A19	10-11-84	814	19800	1858	7379	35	288	39	29110
C100DB	A19	10-11-84	814	14590	1550	4907	35	460	0	21080
C108	-	10-11-84	24hr	572	57	63	4	133	0	697
C108B	-	10-11-84	24hr	581	67	58	6	113	0	712
C117	C11	10-11-84	1047	20210	5315	12430	243	86	77	38270
C117B	C11	10-11-84	1047	17800	5248	11660	244	85	90	35040
C118	C11	10-11-84	1051	16420	4072	10820	108	72	39	31460
C156	C11	10-12-84	1400	409800	70170	141000	76	1494	1109	622100
C156B	C11	10-12-84	1400	382400	69680	148400	60	1404	653	601200
C175	A07	10-13-84	913	35010	8640	15320	0	125	71	59040
C176	A07	10-13-84	915	21980	1520	7938	0	0	0	31440
C195	C13	10-13-84	1354	59160	15260	31750	0	204	121	106300
C195B	C13	10-13-84	1354	66500	18270	34540	17	260	156	119500
C263	C11	10-24-84	1006	14480	4456	7156	41	49	12	26150
C264	C11	10-24-84	1010	12350	3636	7218	217	59	19	23440
C272	A19	10-24-84	1310	11060	3865	8759	279	47	337	24300
C272B	A19	10-24-84	1310	10950	2661	8931	295	68	254	23090
C329	B14	10-26-84	933	1238	263	537	26	79	0	2065
C329B	B14	10-26-84	933	1340	272	629	35	121	0	2276
C337	C01	10-26-84	1040	11470	2849	6580	36	124	102	21040
C337B	C01	10-26-84	1040	11740	2062	8117	32	143	0	21950
C346	A07	10-26-84	1305	131200	29580	108900	0	1174	6156	275800
C346B	A07	10-26-84	1305	122900	20640	100100	0	744	2946	246500
C352	A19	10-26-84	1338	13540	2043	7532	3	117	143	23260
C353	A19	10-26-84	1340	10820	2888	5934	223	47	84	19950
C389	A12	11-8-84	1343	2563	356	2220	169	363	139	5448
C390	A12	11-8-84	1345	2646	508	2974	166	265	8	6302
C396	C15	11-8-84	1430	6393	2000	5283	20	622	10	13710
C396B	C15	11-8-84	1430	6507	1236	4192	21	477	0	11960
C467	A07	11-10-84	1433	10780	2180	10320	193	689	634	24100
C468	A07	11-10-84	1436	8594	1472	7439	134	740	1000	18640
C468B	A07	11-10-84	1436	8684	1826	7582	135	694	963	19190

TABLE 53. PRECISION ESTIMATES FOR GAS CANISTER SAMPLE RESULTS

Hydrocarbon Class[a]	Mean Concentration (ug/m^3)	Sampling Plus Analytical[b] (CV, %)	Analytical[c] (CV, %)
Total Paraffins	60,000	15.8	5.1
Total Olefins	10,000	19.0	18.8
Total Aromatics	27,000	20.9	8.3
Total Halogenated HC	110	72.8	13.4
Total Oxygenated HC	500	32.9	23.5
Unidentified VOC	600	64.3	27.9
Total NMHC[d]	97,000	14.1	5.9

[a] CV for total reflects agreement of values for class totals based on total peak area for a given class.

[b] Estimate of total variability in sampling/analytical process, based on results for duplicate samples.

[c] Estimate of analytical variability, independent of sampling variability, based on results for duplicate analyses.

[d] Excludes oxygenated HC species.

TABLE 54. SPECIE IDENTIFICATION BY GC/FID/PID/HECD AND BY GC/MS FOR SAMPLE C044

Major Specie[a]	Identified by GC/FID/PID/HECD	GC/MS	GC/MS Confidence Level[b]
Paraffins			
n-butane	X		
isopentane	X	-[c]	2
n-pentane	X	X	2
neohexane	X		
cyclopentane	X		
2,3-dimethylbutane	X		
isohexane	X	-[c]	2
3-methlypentane	X	-[c]	2
n-hexane	X	X	2
methylcyclopentane	X	X	2
2,4-dimethylpentane	X		
cyclohexane	X		
isoheptane	X	-[c]	2
3-methylhexane	X	-[c]	2
n-heptane	X	X	2
methylcyclohexane	X	X	2
2,5-dimethylhexane	X		
2,3,4-trimethylpentane	X	X	2
3-methylheptane	X	-[c]	2
2,2,5-trimethylhexane	X		
n-octane	X	X	2
n-nonane	X	X	3
n-decane	X		
n-undecane	X		
Olefins			
T-2-pentene	X		
2-methyl-2-butene	X		
2-methyl-2-pentene	X		
T-2-hexene	X		
1-methylcyclohexene	X		
1-octene	X	-[c]	3
B-pinene	X		
Total Aromatics			
benzene	X	X	2
toluene	X	X	2

(Continued)

TABLE 54. (Continued)

Major Specie[a]	Identified by GC/FID/PID/HECD	GC/MS	GC/MS Confidence Level[b]
Total Aromatics (Continued)			
ethyl benzene	X	X	2
p-xylene/m-xylene	X	X	2
styrene	X		
o-xylene	X	X	2
isopropylbenzene	X		
n-propylbenzene	X		
m-ethyltoluene	X	-[c]	2
1,3,5-trimethylbenzene	X	-[c]	2
o-ethyltoluene	X	-[c]	2
1,2,4-trimethylbenzene	X	-[c]	2

[a] A major specie is defined as an individual compound measured at one (1) ppmv or greater by either analytical technique.

[b] Confidence levels are: 1) identification based on comparison to standard, 2) computer library match of high probability, 3) tentative, manual interpretation

[c] Probable identification. Location of substituted groups not identified.

TABLE 55. SPECIE IDENTIFICATION BY GC/FID/PID/HECD AND BY GC/MS FOR SAMPLE C100D

Major Specie[a]	Identified by GC/FID/PID/HECD	GC/MS	GC/MS Confidence Level[b]
Paraffins			
isopentane	X	-[c]	3
isohexane	X	X	2
n-hexane	X	X	2
methylcyclopentane	X		
isoheptane	X	X	2
3-methylhexane	X	-[c]	3
n-heptane	X	X	2
methylcyclohexane	X	X	2
3-methylheptane	X	-[c]	3
n-octane	X	X	2
Olefins			
No major peaks detected			
Total Aromatics			
toluene	X	X	2
ethylbenzene	X	X	2
p-xylene/m-xylene	X	X	2

[a] A major specie is defined as an individual compound measured at one (1) ppmv or greater by either analytical technique.

[b] Confidence levels are: 1) identification based on comparison to standard, 2) computer library match of high probability, 3) tentative, manual interpretation

[c] Probable identification. Location of substituted groups not identified.

TABLE 56. SPECIE IDENTIFICATION BY GC/FID/PID/HECD AND BY GC/MS FOR SAMPLE C286

Major Specie[a]	Identified by GC/FID/PID/HECD	GC/MS	GC/MS Confidence Level[b]
Paraffins			
isopentane	X		
n-pentane	X	X	2
2,3-dimethylbutane	X		
isohexane	X	-[c]	
3-methylpentane	X	-[c]	2
n-hexane	X	X	2
methylcyclopentane	X	X	2
2,4-dimethylpentane	X	-[c]	
cyclohexane	X	X	2
isoheptane	X	-[c]	
3-methylhexane	X	-[c]	
n-heptane	X	X	2
methylcyclohexane	X	X	2
2,5-dimethylhexane	X	-[c]	
2,3,4-trimethylpentane	X	X	2
3-methylheptane	X	-[c]	
2,2,5-trimethylhexane	X	-[c]	
n-octane	X	X	2
n-nonane	X		
n-decane	X	X	2
n-undecane	X		
Olefins			
1-octene	X		
B-pinene	X		
limonene	X		
1-undecene	X		
Total Aromatics			
benzene	X	X	2
toluene	X	X	2
ethylbenzene	X	X	
p-xylene/m-xylene	X	X	2
styrene	X		
o-xylene	X	X	2
n-propylbenzene	X		

(Continued)

TABLE 56. (Continued)

Major Specie[a]	Identified by GC/FID/PID/HECD	GC/MS	GC/MS Confidence Level[b]
Total Aromatics (Continued)			
m-ethyltoluene	X	-[c]	
1,3,5-trimethylbenzene	X	-[c]	
o-ethyltoluene	X	-[c]	
1,2,4-trimethylbenzene	X	-[c]	
1,2,3-trimethylbenzene	X	-[c]	
indan	X		
indene	X		
m-diethylbenzene	X		
n-butylbenzene	X		
p-diethylbenzene	X		

[a] A major specie is defined as an individual compound measured at one (1) ppmv or greater by either analytical technique.

[b] Confidence levels are: 1) identification based on comparison to standard, 2) computer library match of high probability, 3) tentative, manual interpretation

[c] Probable identification. Location of substituted groups not identified.

TABLE 57. SPECIE IDENTIFICATION BY GC/FID/PID/HECD AND BY GC/MS FOR SAMPLE C348

Major Specie[a]	Identified by GC/FID/PID/HECD	GC/MS	GC/MS Confidence Level[b]
Paraffins			
isopentane	X		
n-pentane	X	X	2
isohexane	X	_[c]	
3-methylpentane	X	_[c]	
n-hexane	X	X	2
methylcyclopentane	X	X	2
cyclohexane	X	X	2
isoheptane	X	_[c]	
3-methylhexane	X	_[c]	
n-heptane	X	X	2
methylcyclohexane	X	X	2
2,5-dimethylhexane	X	_[c]	
2,3,4-trimethylpentane	X	_[c]	
3-methylheptane	X	_[c]	
2,2,5-trimethylhexane	X	_[c]	
n-octane	X		
n-nonane	X	X	2
n-decane	X	X	2
n-undecane	X		
Olefins			
1-methylcyclohexene	X		
1-octene	X		
B-pinene	X		
limonene	X		
1-undecene	X		
Total Aromatics			
benzene	X	X	2
toluene	X	X	2
ethylbenzene	X		
p-xylene/m-xylene	X	X	2
styrene	X		
o-xylene	X	X	2
n-propylbenzene	X		

(Continued)

TABLE 57. (Continued)

Major Specie[a]	Identified by GC/FID/PID/HECD	GC/MS	GC/MS Confidence Level[b]
Total Aromatics (Continued)			
m-ethyltoluene	X	–[c]	
o-ethyltoluene	X	–[c]	
1,2,4-trimethylbenzene	X		
1,2,3-trimethylbenzene	X		
indan	X		
indene	X		
m-diethylbenzene	X		
n-butylbenzene	X		
p-diethylbenzene	X		

[a] A major specie is defined as an individual compound measured at one (1) ppmv or greater by either analytical technique.

[b] Confidence levels are: 1) identification based on comparison to standard, 2) computer library match of high probability, 3) tentative, manual interpretation

[c] Probable identification. Location of substituted groups not identified.

TABLE 58. RESULTS OF QUALITY CONTROL CHECKS FOR SOIL OIL AND GREASE ANALYSIS (EPA Method 413.1)

QC Check	Units	Number of Analyses	Average Value	Relative Standard Deviation	Range
Blank	mg/g	6	2.0	98%	0-4.9
QC Standard	% recovery	5[a]	104[a]	7.6%	89.5-108[a]
Duplicate analysis	% difference	2	0.8	190%	0.4-1.1

[a] Outlier of 500% recovery omitted.

TABLE 59. RESULTS OF DUPLICATE SAMPLES AND ANALYSIS OF SLUDGE SAMPLES FOR % SOLIDS, WATER, AND OIL ANALYSIS

Field[a] Sample ID	Sampling Date	Sampling Time	Analysis Date	% Solids	% Water[c]	% Oil[d]
C032	10-10-84	940	2-04-85[b]	8.49	59.3	32.2
C047	10-10-84	1145	2-04-85[b]	9.15	57.6	33.2
C032	10-10-84	940	2-20-86	8.53	(69.2,75.2, 68.4)	20.6
C032	10-10-84	940	2-20-86	8.92	(76.4,69.4, 71.7)	18.6
C032[e]	10-10-84	940	2-20-86	8.55	(74.4,72.8)	17.8
C032[e]	10-10-84	940	2-20-86	8.43	(73.0,70.8)	19.7
C032	10-10-84	940	3-28-86	8.55	(74.8,71.4)	18.4
C032	10-10-84	940	3-28-86	8.86	(65.7,69.6)	23.5
C032[e]	10-10-84	940	3-28-86	8.38	(65.4,36.3)[b]	40.8[b]
Averages (RSD)				8.60 (2.4%)	71.6 (4.2%)	19.8 (11%)

[a] Different container of C032 sample used for each analysis date

[b] Result not used in calculating average value (see text)

[c] Results in parentheses represent duplicate determinations

[d] Determined by difference

[e] Spiked sample

% water in the sample based upon the unspiked and spiked sample weights. The % oil was determined by difference. The % recovery of the spikes are given in Table 60.

TABLE 60. RESULTS OF SPIKE RECOVERY OF SPIKED SLUDGE SAMPLES FOR % SOLIDS, WATER, AND OIL ANALYSIS

Field Sample ID	Analysis Date	Weight of Oil Spike (g)	Recovered Weight of Oil Spike (g)	% Recovery
C032	2-20-86	2.13	1.96	92.0
C032	2-20-86	4.35	3.96	91.0
C032	3-28-86	1.72	1.58	91.9
Average (RSD)				91.6 (0.66%)

SECTION 11

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APPENDIX A

RESULTS OF TESTING BY CHEVRON CORPORATION

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INTRODUCTION

Chevron representatives were present during portions of the Radian test effort and collected soil and waste samples. They also made measurements of soil and ambient temperatures. The analytical results of the Chevron testing differ in some respects from the analytical results obtained by Radian. This appendix presents conclusions which reflect the use of Chevron data in place of the Radian data and presents the Chevron analytical results. The analytical method used by Chevron is given in Appendix P (1).

CONCLUSIONS

The Chevron data differ from the Radian data in several respects. The simulated distillation of the applied oil yields a volatile organics content (BP $\leq$ 450°F) of approximately 11% in the oil fraction or 2.2% in the applied sludge. Radian's analyses (by purge and trap) showed an average volatile organic content of 0.782% in the applied sludge. The Chevron results of the oil content analyses indicate a much higher oil loading for the subsurface application plot (C) than for the surface application plot (A) (3980 kg vs. 1580 kg), whereas Radian's soil oil data showed roughly 10% higher oil content for the surface application plot.

The results of the Chevron testing and analyses lead, in some cases, to project conclusions differing from those given in Section 2. Conclusions that would not be affected are those pertaining to the change in emissions with time, the effect of diurnal temperature fluctuations, the behavior of individual compounds of the applied waste, and the CO_2 release rates. The conclusions which would be affected are the fraction of applied volatile organics being emitted from each plot, the effect of application method on VOC emissions, the disappearance of oil, the effect of tilling on VOC emissions, the applicability of the Thibodeaux-Hwang model, and the suitability of the sampling and analytical methods used. Each of the differing conclusions are discussed below.

The overall percent emissions of volatile organics are lower if the Chevron definition of volatile organics is used, i.e., volatile organics are those that are distilled below an ASTM distillation temperature of 450°C. The volatile organic content of the sludge is then three times higher (2.2% vs. Radian value of 0.78). Therefore, the volatile organic levels in the plots are higher, 182 kg for Plot A and 455 kg for Plot C versus 110 kg for each of the plots using the Radian volatile organics concentration. The apparent higher loading of volatile organics results in a corresponding

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decrease in measured and estimated emissions as a percentage of the applied volatile organics. (The difference in loading between the two plots is explained below.)

The Chevron analyses of the oil content of the soil samples collected shortly after sludge application indicate a substantially higher loading of the subsurface applied plot (Plot C) when compared with the loading on the surface-applied plot (Plot A). If this is the case, the subsurface application method is effective in reducing emissions of the applied volatile organics. The cumulative measured emissions are equivalent to 2.8% and 1.3% of the applied volatile organics for Plots A and C, respectively. Likewise the estimated total emissions for the test period are 18.3% and 8.6% of the applied volatile organics for Plots A and C, respectively, using Chevron's value for VOC content. (If Radian values for VOC content of the sludge were used, the cumulative measured VOC emissions would be equivalent to 8.3% and 3.8% of the applied VOC for Plots A and C, respectively. Similarly, the estimated total cumulative VOC emissions would be equal to 53% and 25% of the applied VOC for Plots A and C, respectively.)

The percentage increases in emissions due to the tilling would remain the same, since these factors are independent of loading. However, the fraction of applied material emitted from Plot A would be higher than estimated using the Radian loadings. Conversely, the fraction of applied material emitted from Plot C would be substantially lower. Thus, the Chevron data indicate that even immediately after tilling, the fractional emissions from the subsurface plot are substantially less than those from the surface applied plot.

There appeared to be a statistically significant decrease in the oil content of control points on Plots A and C decreased during the five-week test period according to Chevron's results. The oil content of the soil from 2 control points on Plot A (surface) showed a decrease in oil content of 0.30 to 0.80% by weight. This is equivalent to approximately 510-1350 kg of oil, or about 32-85% of the applied oil. The oil content of the two control points on Plot C (subsurface) indicated a decrease in soil content of approximately 370-1280 kg, or about 9-32% of the applied oil (assuming the high application rate for Plot C). Thus, it would appear that the percent removal/disappearance of oil, by whatever means (volatilization, biodegradation, leaching, photochemical reaction), may have been somewhat less in the subsurface application plot.

The Thibodeaux-Hwang model was applied to the landtreatment system using the loadings estimated from the Chevron data. The results were calculated for n-heptane, n-nonane, and toluene applied to Plots A and C. In general, the ratios of the predicted to the estimated values of the total emissions are about the same as those calculated with Radian data (Section 9).

SIGNIFICANCE OF CHEVRON RESULTS

The method used by Chevron to estimate the volatile organic content of the sludge is quite different from that used by Radian. Since both methods of estimation are somewhat arbitrary, the use of one method in preference to the other depends upon its utility. The stripping/purge method was employed in an earlier study to characterize the volatility of landtreatment sludges (2). Purge-and-trap techniques are also generally recognized methods for determining the volatile compound content of liquids and solids (3,4). The simulated distillation method used by Chevron may be just as useful for characterizing sludges, but it seems apparent that the results cannot be directly compared to the results of stripping/purge-and-trap tests.

The Chevron modified oven-drying technique (MODT) gave higher values for the oil content of soil samples than the EPA Reference Method (413.1) used by Radian. The Chevron method limits oil losses during sample drying and therefore may be more accurate. Data from both methods indicate a considerable degree of variability. The coefficient of variation (CV) for the Radian data is 25.3%, while the Chevron data exhibited a CV of 14.4%. It should be noted, however, that the CV includes, in addition to the analytical variability, the variability in oil content across the test plots and the variability over time. In their MODT analyses, Chevron performed duplicate analyses of 12 samples. The average difference in oil content (dry weight basis) between duplicate analyses was 4.3% of their average value. Another indication of the accuracy of the MODT is the relatively small standard deviations of the analyses of soil samples taken from the control points during each week of sampling. These percent relative standard deviations vary between 2.9% and 7.9%, with an average value of 4.7% and a median value of 3.8%.

The MODT technique was unavailable to Radian at the time of their soil analyses, and therefore, only the Radian results (using the EPA Reference Method) were used in preparing the main body of the technical report. The Radian analytical results indicate that a greater precision is needed in the analyses of oil in soil to detect oil disappearance in soil. Chevron's data appear to support this conclusion. Chevron's soil analyses showed a much larger oil content for the soil in Plot C, while the Radian results indicated nearly equal amounts in Plots A and C. There is no readily apparent reason for this significant difference in results. The authors also note that, while Chevron found very different oil contents in the test plots, the absolute emission rates from Plots A and C were equal within experimental error. There is no cause-and-effect relationship between these two phenomena; the near equality of observed emission rates appears to be only coincidental.

Other than the oil content of the soil samples, there are no data to indicate unequal levels of sludge application to the test plots. Factors supporting unequal loading are generally associated with the differences in application techniques. Resistance from the soil could cause lower sludge flow through the applicator tines during subsurface injection. On the other hand, a smaller liquid head would exist with the tines raised during surface spreading, and this would also result in lower sludge flow rates. Non-linear flow could have been present due to the non-linear change in liquid head as the horizontal cylindrical applicator tank was emptying or due to settling of the sludge in the tank during the application process. Attempts were made to minimize the effects of such changes on loading levels through the choice of truck path across the plots (see p. 8). Given this application protocal, the authors do not believe that there could have reasonably been a factor of two differences in the amount or composition of sludge applied to the two plots. Also, it appears quite fortuitous that subsurface application could reduce the VO emission rate from Plot C by a factor equal to the increased oil loading on Plot C, thus resulting in approximately equal emissions from the two plots.

SAMPLING AND ANALYTICAL RESULTS

The analyses of the sludge for % solids, oil, and water are given in Table A-1. Radian's results are included for comparison. The analytical procedure used by Chevron is given in Appendix P. The amount of volatile organics in the sludge was determined by a simulated distillation (ASTM D 2887). Results are given in Table A-2. The soil moisture and oil content analytical results are given in Table A-3 and summarized in Table A-4. Radian results, included for comparison, were based on the analytical procedure given in Appendix O.

The oil contents of the soil samples collected and analyzed by Chevron were statistically analyzed to estimate the oil application rate to Plots A and C and to estimate the disappearance of oil from the soil at the control points over the five-week test period. The results of the statistical analyses are summarized in Tables A-5 and A-6.

The oil loading was estimated by comparing the oil content of the soil samples taken from Plots A and C immediately after application to the oil content of the soil in the control Plot B. It was assumed that the oil content of Plot B was representative of the conditions in Plots A and C immediately preceding sludge application. As indicated in Table A-5, there is a statistically significant difference in the apparent oil loading of the two plots.

The oil content of soil samples taken from the same location during weeks 1 and 5 of the test were used to estimate oil disappearance from the zone of incorporation. The mean oil contents at these times and the apparent disappearance of oil are tabulated in Table A-6. There appear to be decreases in the oil levels ranging from 0.30 to 0.80%. The results of the statistical analyses are also included in Table A-6. It appears that the decreases in oil levels in the soil are statistically significant, although only one difference was significant above the 95% probability level.

DISCUSSION OF MODELING RESULTS

The Thibodeaux-Hwang model was applied to Plots A and C using the Chevron data to estimate loadings for three representative compounds: n-heptane, n-nonane, and toluene. The results are summarized in Table A-7 and graphically presented in Figures A-1 through A-6. The predicted emission rates for both the cases with and without tilling are shown, and the measured rates are also included on the graphs. In general, the predicted rates are consistently higher than the measured rates for the selected compounds. In some cases, the emission rate curve for the cases in which the effects of tilling were not considered is truncated before the end of the test period. In these cases, the model has predicted that all the applied compound has been volatilized.

TABLE A-1. RESULTS OF DETERMINATION OF % SOLIDS, OIL, AND WATER IN LAND TREATMENT SLUDGE

Analyst	Field Sample	Wt. % Solids	Wt. % Water	Wt. % Oil
Chevron	C032	7.8	72.6	19.0
Radian	C032	8.6	71.6	19.8
Chevron	C047	8.5	70.1	20.8

TABLE A-2. RESULTS OF CHEVRON ANALYSES OF LAND TREATMENT SLUDGE

% Distilled	--Boiling Point °F-- C032[a]	C047[b]
Initial Boiling Point	194	210
2	376	322
5	427	377
10	457	420
25	545	530
50	667	678
75	771	805
90	845	1026
98	968	1026

[a] Approximately 9% distilled at 450°F (VOC content)

[b] Approximately 13% distilled at 450°F (VOC content)

TABLE A-3. RESULTS OF ANALYSES OF SOIL GRAB SAMPLES

Field Sample ID	Sampling Location	Sampling Date	Sampling Time	Chevron Analytical Results			Radian Analytical Results			
				Percent Moisture	Oil Content of Soil, mg/g		Percent Moisture	Oil Content of Soil, mg/g		Microbe Count bug/g 10x5
					Wet	Dry		Wet	Dry	
C022	A07	10-9-84	1805							
C026	A07	10-10-84	730							
C027	A19	10-10-84	735				11.0	51	57.3	
C036	A19	10-10-84	1110	8.39	91.0	99.3	12.0	85	96.6	3
C042	A20	10-10-84	1140	8.46	96.9	105.9	11.0	86	96.6	
C052	A07	10-10-84	1240	12.40	66.1	75.5	12.0	44	50.0	
	A07	10-10-84	1240	12.17	64.6	73.6				
C059	A03	10-10-84	1400	12.70	75.5	86.5				
C066	A12	10-10-84	1505	13.74	84.3	97.7				
	A07	10-10-84	1533	11.62	67.9	76.8				
	A19	10-10-84	1617	8.86	86.1	94.5				
	A19	10-10-84	1617	15.05	83.2	97.9				
	A14	10-10-84	1723	9.26	95.6	105.4				
	A17	10-11-84	534	7.37	100.7	108.7				
C088	A13	10-11-84	625	9.10	89.0	97.9				
	A07	10-11-84	719	10.88	62.1	69.7				
	A19	10-11-84	806	9.80	91.9	101.9				
	A07	10-11-84	915	12.02	60.3	68.5				
	A07	10-11-84	915	10.58	64.4	72.0				
C114	A19	10-11-84	1004	10.62	92.8	103.8	22.0	16	20.5	6
	A14	10-11-84	1119	8.92	72.5	79.6				
C124	A16	10-11-84	1136	8.42	100.0	109.2	9.4	60	66.2	2
C132	A19	10-12-84	921				11.0	51	57.3	52
C140	A07	10-12-84	1053				9.0	45	49.5	3
	A07	10-12-84	1308	9.37	67.4	74.4				
	A19	10-12-84	1402	9.05	94.3	103.7				
	A06	10-12-84	1424	22.41	58.8	75.8				
C160	A12	10-12-84	1424	26.67	57.5	78.4				
C183	A13	10-13-84	1458				10.0	52	57.8	45
C191	A07	10-13-84	1043				11.0	52	58.4	5
C196	A19	10-13-84	1410				9.6	35	38.7	15
C217	A11	10-23-84	1007				9.5	77	85.1	21
C220	A19	10-23-84	1038							
C243	A19	10-23-84	1500				9.3	86	94.8	30
C253	A07	10-24-84	845				8.5	51	55.7	9
C259	A19	10-24-84	950							
C268	A15	10-24-84	1104				8.5	74	80.9	78
C304	A15	10-25-84	800				9.7	58	64.2	59

(Continued)

TABLE A-3. (Continued)

Field Sample ID	Sampling Location	Sampling Date	Sampling Time	Chevron Analytical Results			Radian Analytical Results			
				Percent Moisture	Oil Content of Soil, mg/g		Percent Moisture	Oil Content of Soil, mg/g		Microbe Count bug/g 10x5
					Wet	Dry		Wet	Dry	
C307	A05	10-25-84	824							
C322	A07	10-25-84	1340				10.0	50	55.6	48
C335	A19	10-26-84	1020							
C339	A08	10-26-84	1319				9.9	46	51.1	19
C349	A19	10-26-84					11.0	64	71.9	19
	A05	11-7-84	12-1500	7.76	61.2	66.3				
	A10	11-7-84	12-1500	8.00	74.4	80.9				
	A12	11-7-84	12-1500	8.50	73.4	80.2				
	A17	11-7-84	12-1500	5.96	85.0	90.4				
	A19	11-7-84	12-1500	8.60	89.8	98.2				
	A19	11-7-84	12-1500	8.83	88.6	97.2				
	A21	11-7-84	12-1500	9.11	93.0	102.3				
C367	A03	11-8-84	931							
C375	A19	11-8-84	1120	8.00	81.5	88.6	9.4	73	80.6	21
	A07	11-8-84	1208	10.84	64.0	71.8				
	A07	11-8-84	1229	9.12	60.8	66.9				
C387	A12	11-8-84	1327				10.0	66	73.3	28
	A19	11-8-84	1415	7.08	88.3	95.0				
	A19	11-8-84	1415	6.71	85.8	92.0				
C405	A07	11-9-84	855	11.35	61.0	68.8	9.4	46	50.8	10
C416	A19	11-9-84	1045	7.35	84.8	91.5	12.0	69	78.4	
C422	A20	11-9-84	1307							
	A07	11-9-84	1401	9.40	66.4	73.3				
	A19	11-9-84	1418	10.41	84.3	94.1				
C446	A07	11-10-84	1006				12.0	39	44.3	34
C454	A18	11-10-84	1142							
C461	A05	11-10-84	1310				10.0	35	38.9	25
C480	A07	11-12-84	851				12.0	43	48.9	9
C486	A19	11-12-84	954				13.0	68	78.2	20
C503	A21	11-12-84	1224							
C016	B11	10-9-84	1710							
C019	B04	10-9-84	1810							
	B06	10-10-84	1343	7.40	65.2	70.4				
	B17	10-10-84	1415	4.81	84.3	88.6				
	B15	10-10-84	1653	5.04	77.5	81.6				
	B11	10-10-84	1709	6.17	61.7	65.8				
	B06	10-11-84	800	9.19	60.6	66.9				
	B17	10-11-84	838	4.72	100.9	105.9				

(Continued)

TABLE A-3. (Continued)

				Chevron Analytical Results			Radian Analytical Results			
					Oil Content of Soil, mg/g			Oil Content of Soil, mg/g		
Field Sample ID	Sampling Location	Sampling Date	Sampling Time	Percent Moisture	Wet	Dry	Percent Moisture	Wet	Dry	Microbe Count bug/g 10x5
C119	B15	10-11-84	1046	7.67	81.1	87.8	8.6	32	35.0	
	B11	10-11-84	1220	7.76	81.1	87.9				
C166	B15	10-12-84	1534				9.9	49	54.4	4
	B18	10-12-84	1617	7.24	80.0	86.2				
C188	B13	10-13-84	1129				9.5	52	57.5	
C226	B01	10-23-84	1150				7.7	43	46.6	7
C276	B13	10-24-84	1351				9.6	41	45.4	26
C302	B03	10-25-84	751				8.2	47	51.2	5
C358	B06	10-26-84	1425				9.4	49	54.1	21
	B01	11-7-84	12-1500	7.05	66.8	71.9				
	B03	11-7-84	12-1500	9.24	66.4	73.2				
	B08	11-7-84	12-1500	8.80	70.4	77.2				
	B13	11-7-84	12-1500	6.86	87.8	94.3				
	B15	11-7-84	12-1500	7.73	83.3	90.3				
	B20	11-7-84	12-1500	7.28	91.2	98.4				
C379	B19	11-8-84	1224				11.0	46	51.7	53
C410	B03	11-9-84	932				11.0	55	61.8	5
C458	B04	11-10-84	1230				9.7	46	50.9	1
C505	B21	11-12-84	1255				9.9	61	67.7	9
C013	C04	10-9-84	1715							
C028	C15	10-10-84	740							
C029	C11	10-10-84	745				8.5	60	65.6	
C035	C11	10-10-84	1055	11.32	102.0	115.0				
C041	C15	10-10-84	1130	13.47	92.2	106.6				
C053	C10	10-10-84	1250	9.67	89.4	99.0	11.0	47	52.8	21
C054	C15	10-10-84	1230							
C061	C19	10-10-84	1417	14.04	83.5	97.1				
C068	C09	10-10-84	1520	13.55	93.6	108.3				
	C11	10-10-84	1608	18.80	87.7	108.0				
	C15	10-10-84	1720	13.44	90.6	104.7				
	C10	10-10-84	1810	10.60	95.4	106.7				
C093	C11	10-11-84	640	12.86	86.4	99.2	9.9	34	37.7	
	C15	10-11-84	627	6.99	96.0	103.2				
	C15	10-11-84	627	7.47	95.5	103.2				
	C07	10-11-84	715	11.02	97.6	109.7				
	C09	10-11-84	828	13.08	86.9	100.0				
	C06	10-11-84	916	26.37	144.0	195.6				
C107	C15	10-11-84	945	7.80	87.0	94.4	12.0	54	61.4	

(Continued)

TABLE A-3. (Continued)

Field Sample ID	Sampling Location	Sampling Date	Sampling Time	Chevron Analytical Results			Radian Analytical Results			
				Percent Moisture	Oil Content of Soil, mg/g		Percent Moisture	Oil Content of Soil, mg/g		Microbe Count bug/g 10x5
					Wet	Dry		Wet	Dry	
C115	C11	10-11-84	1034	14.33	80.3	93.7				
	C17	10-11-84	1122	7.58	126.8	137.2				
C144	C15	10-12-84	1136				11.0	38	42.7	
	C15	10-12-84	1312	9.90	104.0	115.4				
C155	C11	10-12-84	1345				8.7	22	24.1	4
	C05	10-12-84	1425	8.84	90.7	99.5				
C193	C13	10-13-84	1338				13.0	44	50.6	61
C200	C02	10-13-84	1417				12.0	63	71.6	
C202	C11	10-13-84	1443				10.0	53	58.9	10
C205	C15	10-13-84	1514							
C214	C11	10-23-83	931				9.1	104	114.4	10
C230	C02	10-23-84	1210				9.0			3
C242	C19	10-23-84	1455							
C265	C19	10-24-84	1025				9.6	61	67.5	12
C273	C01	10-24-84	1318							
C279	C13	10-24-84	1437				8.6			51
C290	C14	10-25-84	602							
C295	C15	10-25-84	640				10.0	48	53.3	38
C306	C19	10-25-84	816				9.5	65	71.8	65
C325	C13	10-26-84	850				7.6	98	106.1	29
C334	C01	10-26-84	1025							
C355	C15	10-26-84	1355				9.3	32	35.3	16
	C05	11-7-84	12-1500	6.35	83.6	89.3				
	C10	11-7-84	12-1500	6.17	99.2	105.7				
	C12	11-7-84	12-1500	10.20	89.7	99.9				
	C17	11-7-84	12-1500	5.25	118.1	124.6				
	C17	11-7-84	12-1500	4.84	117.5	123.5				
	C19	11-7-84	12-1500	6.64	107.1	114.7				
	C19	11-7-84	12-1500	6.71	100.1	107.3				
	C21	11-7-84	12-1500	5.37	112.6	119.0				
	C21	11-7-84	12-1500	5.21	104.6	110.3				
	C15	11-8-84	1112	8.09	95.4	103.8				
	C15	11-8-84	1112	7.07	93.7	100.8				
C386	C11	11-8-84	1252	8.68	90.4	99.0	12.0	62	70.5	108
C394	C15	11-8-84	1415	7.51	88.1	95.3	9.3	54	59.5	50
C399	C14	11-8-84	1518							
	C11	11-8-84	1501	8.15	94.2	102.6				

(Continued)

TABLE A-3. (Continued)

Field Sample ID	Sampling Location	Sampling Date	Sampling Time	Chevron Analytical Results: Percent Moisture	Chevron: Oil Content of Soil, mg/g: Wet	Chevron: Oil Content of Soil, mg/g: Dry	Radian Analytical Results: Percent Moisture	Radian: Oil Content of Soil, mg/g: Wet	Radian: Oil Content of Soil, mg/g: Dry	Radian: Microbe Count bug/g 10x5
C407	C11	11-9-84	915	8.43	89.8	98.1	11.0	40	44.9	27
	C15	11-9-84	1105	9.51	93.8	103.7				
	C15	11-9-84	1105	8.51	81.5	89.1				
	C11	11-9-84	1331	9.69	77.6	85.9				
C429	C04	11-9-84	1409							
C433	C06	11-9-84	1442				9.5	44	48.6	2
C444	C05	11-10-84	930				12.0	50	56.8	18
C450	C21	11-10-84	1051							
C469	C11	11-10-84	1407				14.0	53	61.6	66
C476	C15	11-12-84	837				9.7	79	87.5	
C484	C21	11-12-84	940							
C501	C13	11-12-84	1221				10.0	56	62.2	120

TABLE A-4. SUMMARY OF ANALYTICAL RESULTS FOR SOIL GRAB SAMPLES

		Radian			Chevron		
Plot	Sampling Period	Moisture Content, Wt. %	Oil Content (Wet), mg/g	Oil Content (Dry) mg/g	Moisture Content, Wt. %	Oil Content (Wet), mg/g	Oil Content (Dry), mg/g
A	10/10-10/13	11.7 ± 3.6	49 ± 25	59.2 ± 22.2	10.18 ± 1.78	79.3 ± 14.5	91.6 ± 13.9
	10/23-10/26	9.6 ± 0.8	63 ± 14	69.9 ± 14.9			
	11/7-11/12	11.0 ± 1.3	55 ± 15	61.7 ± 16.4	8.67 ± 1.51	77.2 ± 11.6	83.3 ± 12.2
B	10/10-10/13	9.3 ± 0.5	44 ± 9	49.0 ± 10.0	6.67 ± 1.47	76.9 ± 12.1	82.2 ± 13.0
	10/23-10/26	8.7 ± 0.8	45 ± 3.2				
	11/7-11/12	10.4 ± 0.6	52 ± 6	58.0 ± 7.0	7.82 ± 0.89	77.7 ± 10.1	84.2 ± 10.5
C	10/10-10/13	10.7 ± 1.4	46 ± 12	51.7 ± 14.0	12.16 ± 4.45 (11.62 ± 3.01)[a]	96.3 ± 14.9 (91.7 ± 6.1)[a]	110.3 ± 22.2 (105.8 ± 10.4)[a]
	10/23-10/26	9.1 ± 0.7	68 ± 26	74.7 ± 27.8			
	11/7-11/12	10.9 ± 1.5	55 ± 11	61.5 ± 12.4	7.60 ± 1.62	94.2 ± 10.8	101.9 ± 10.3

[a] With one outlier removed.

TABLE A-5. ESTIMATE OF OIL APPLIED TO PLOTS A AND C (USING CHEVRON'S DATA)

			Oil Content (Wt %)[a]		Oil Applied (Wt %)[a]	
Plot	Sampling Episode	Number of Samples	Average	Standard Deviation[b]	Average	95% Confidence Interval
A	Initial[c]	9	8.22	1.30	0.94	(-0.17, 2.05)
	Following application	19	9.16	1.39		
C	Initial[c]	9	8.22	1.30	2.36	(1.32, 3.40)
	Following application	17	10.58	1.04		

[a] Dry basis.

[b] Variability includes both within- and between-sampling location variability.

[c] Based on oil content measurments from Plot B.

TABLE A-6. STATISTICAL SIGNIFICANCE OF OIL DISAPPEARANCE

Location	Week	# of Samples	Mean Oil Content (Wt %)	Standard Deviation (Wt %)	Difference (Wt %)	Standard Error of Difference (Wt %)	T-Statistic	Prob. [Diff]>0
A07	1	5	7.31	0.304	0.30	0.200	1.48	90.9
	5	4	7.02	0.289				
A19	1	5	10.10	0.324	0.80	0.203	3.94	99.8[a]
	5	5	9.30	0.319				
C11	1	4	10.40	0.942	0.76	0.58	0.128	87.4
	5	4	9.64	0.726				
C15	1	5	10.49	0.752	0.69	0.476	1.44	90.0
	5	3	9.80	0.376				

[a] The decrease in oil content is statistically significant at the 95% probability level.

TABLE A-7. PREDICTED AND ESTIMATED EMISSIONS FROM PLOT A AMD PLOT C

	Amount Applied, g		Total Emissions--with Tilling, g			
			Plot A		Plot C	
Compound	Plot A	Plot C	Predicted	Estimated	Predicted	Estimated
n-Heptane	1254	1986	1252	977	1972	1520
n-Nonane	1153	1827	925	838	1313	1180
Toluene	3367	5333	3355	1620	5256	2430

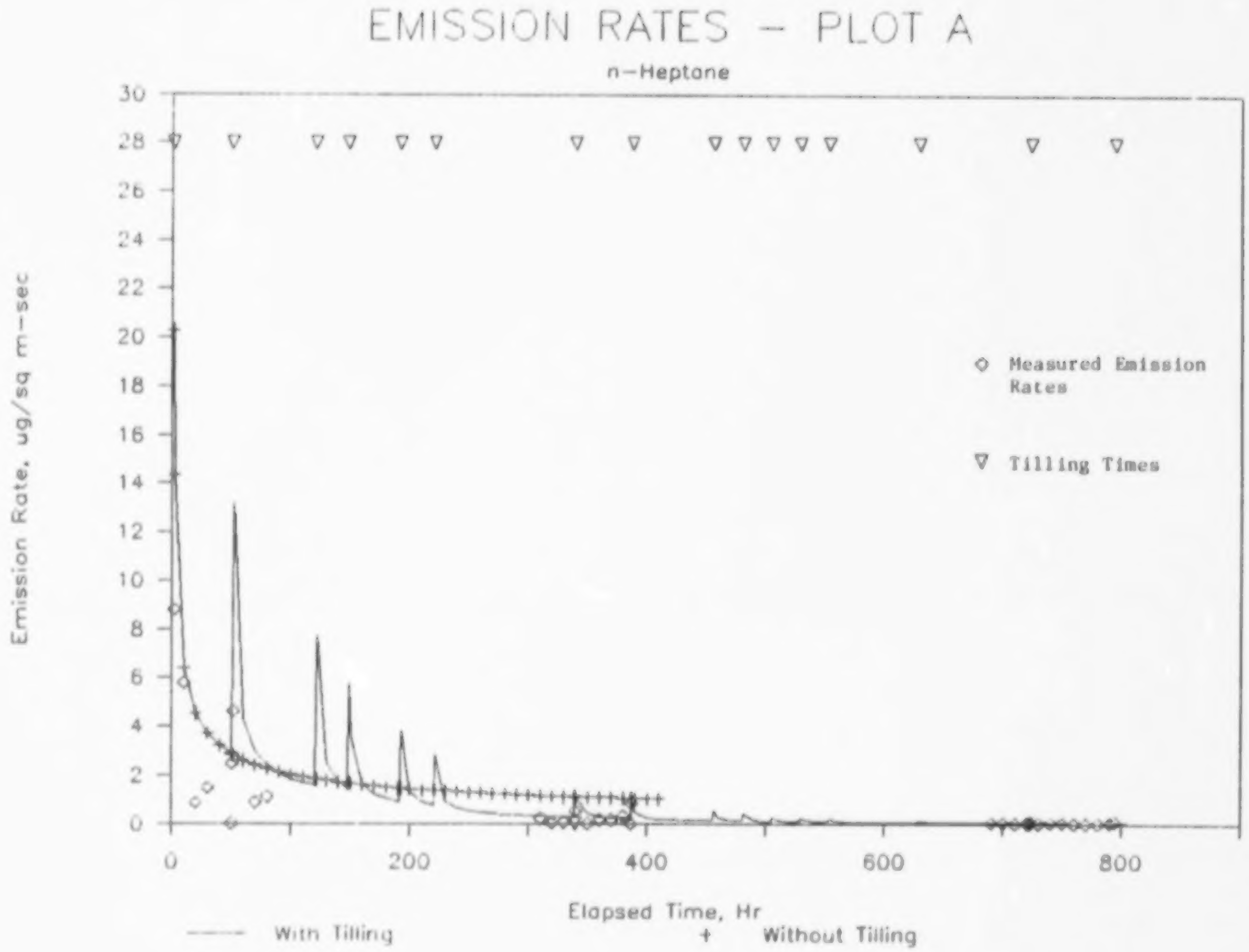

Figure A-1. Predicted Emission Rates of n-Heptane from Plot A with 8000 kg of Sludge Applied

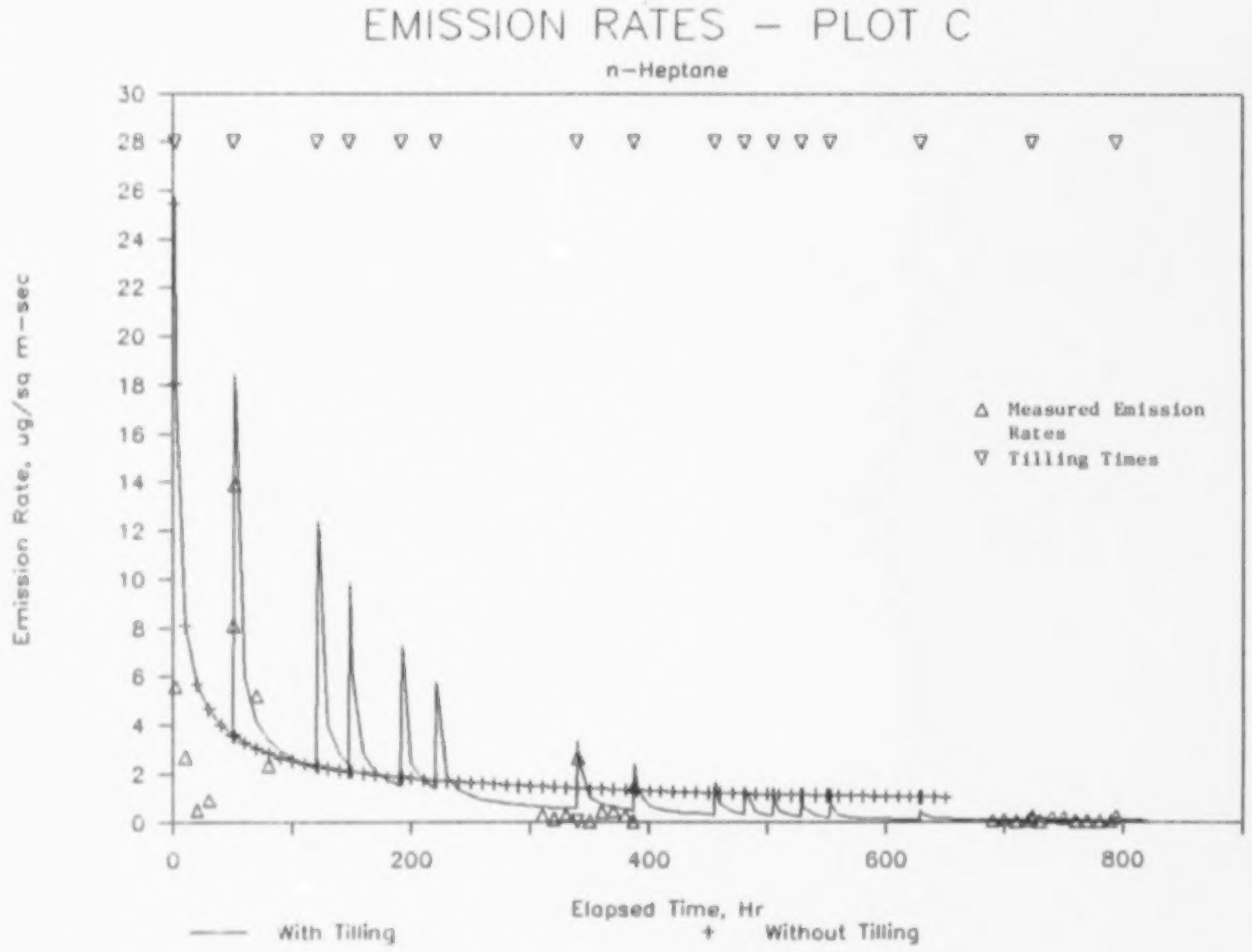

Figure A-2. Predicted Emission Rates of n-Heptane from Plot C with 20,000 kg Sludge Applied

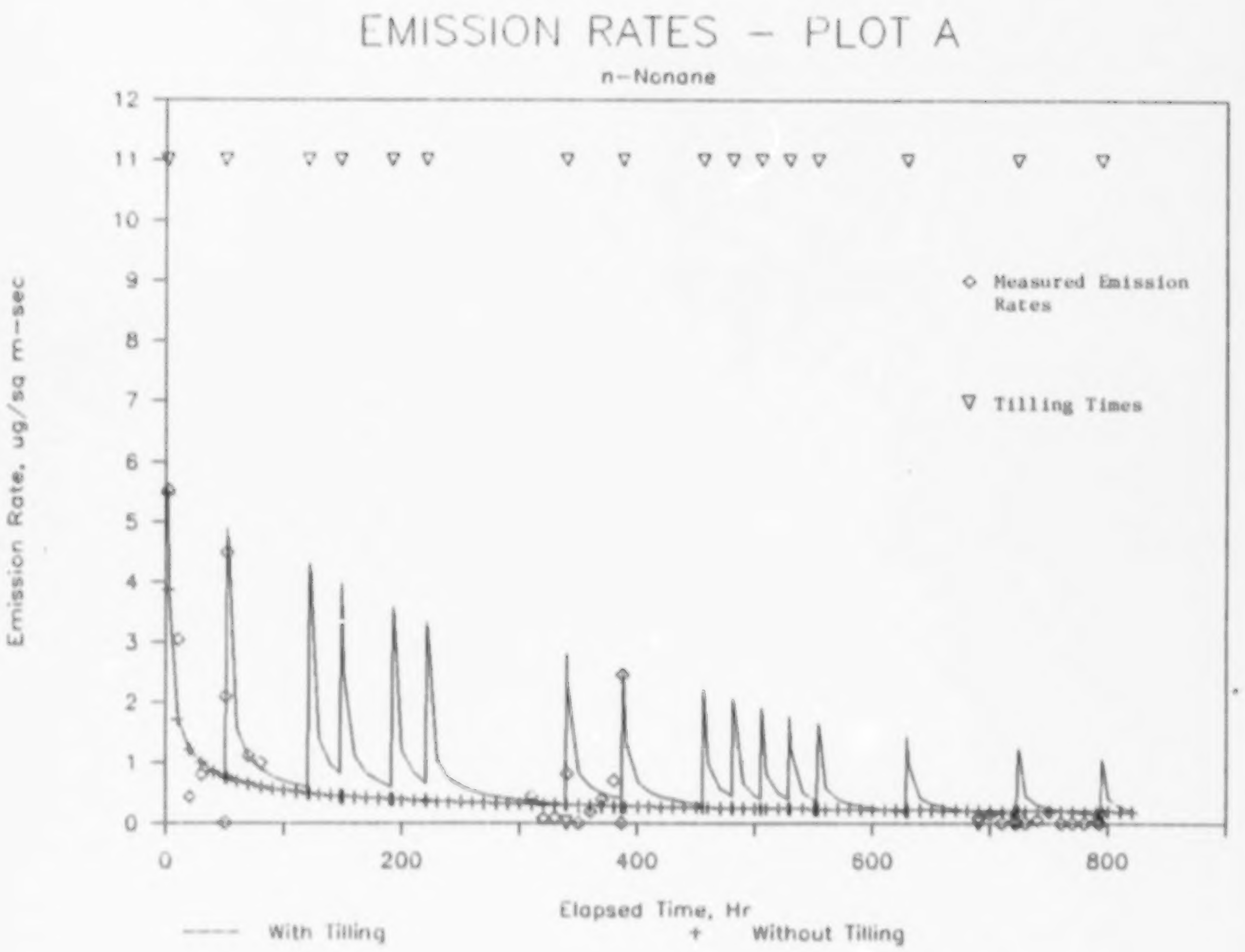

Figure A-3. Predicted Emission Rates of n-Nonane from Plot A with 8000 kg Sludge Applied

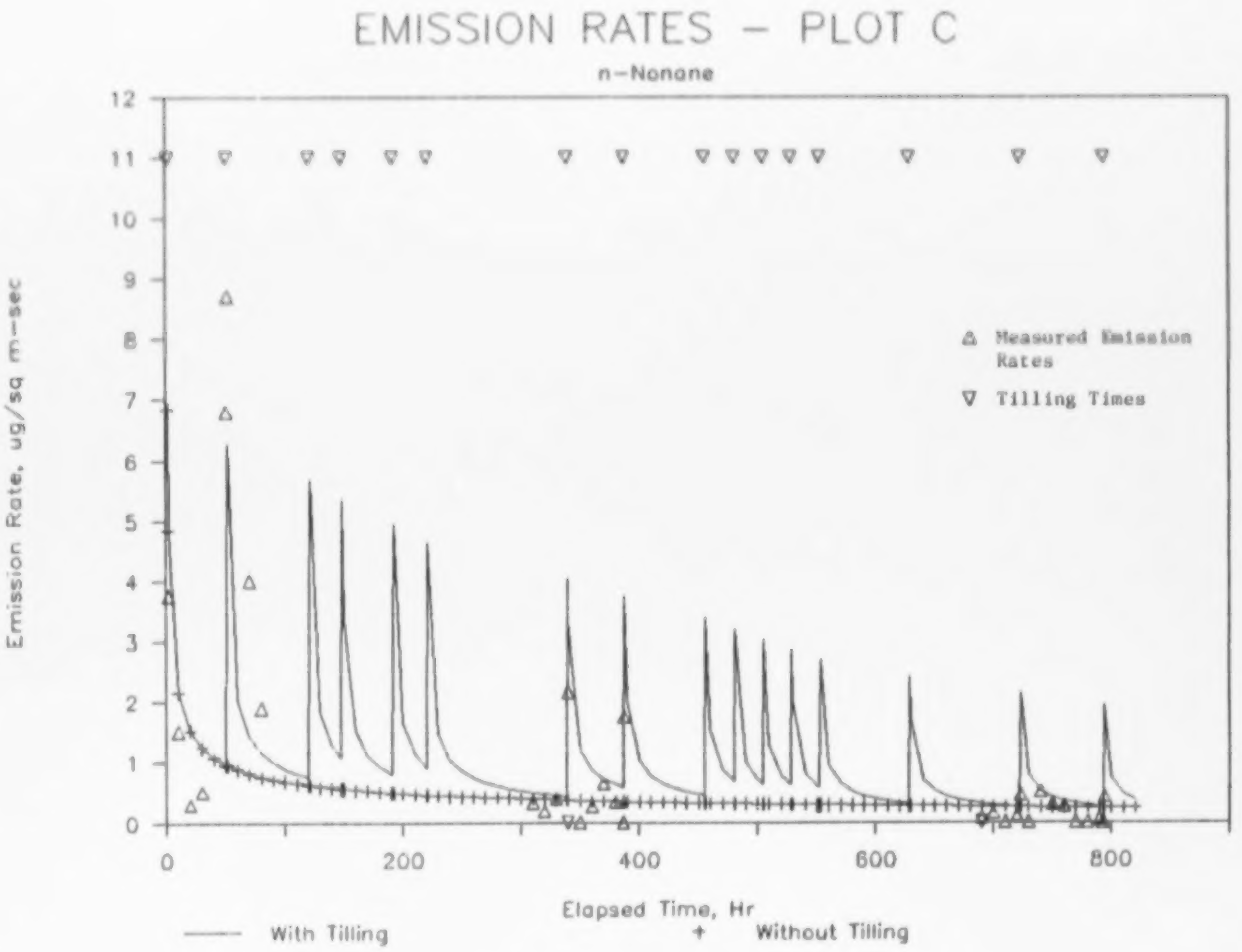

Figure A-4. Predicted Emission Rates of n-Nonane from Plot C with 20,000 kg Sludge Applied

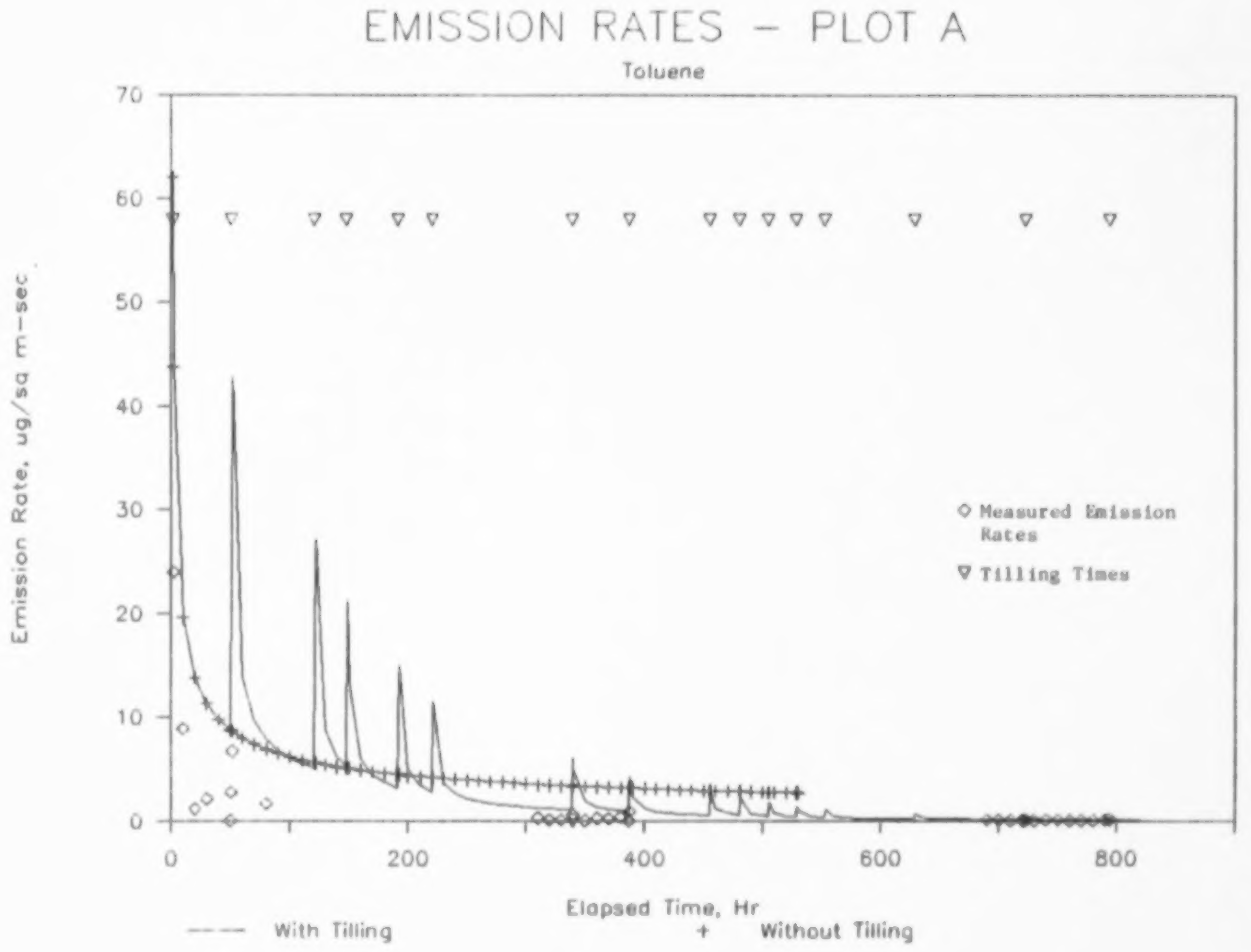

Figure A-5. Predicted Emission Rates of Toluene from Plot A with 8000 kg Sludge Applied

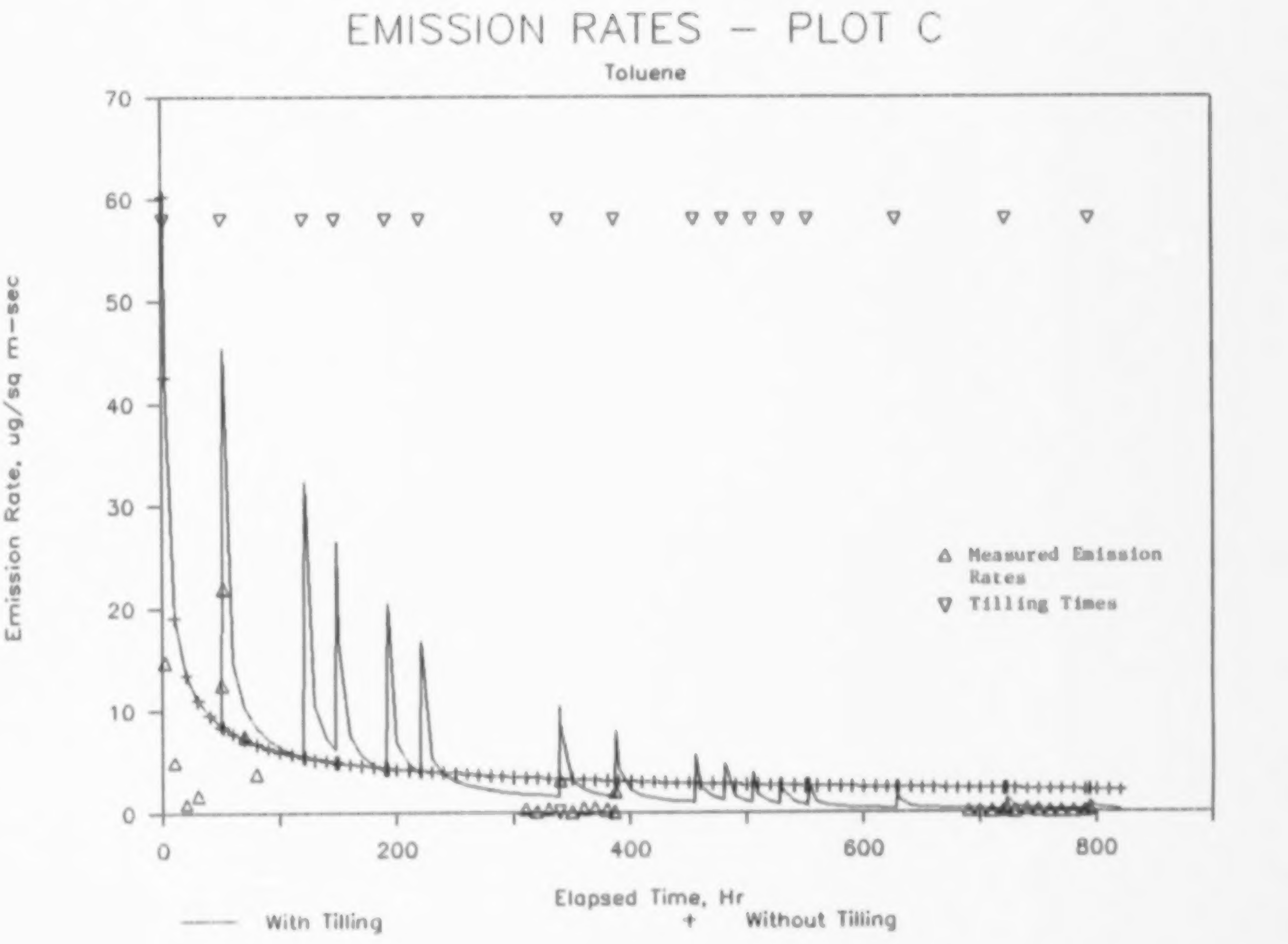

Figure A-6. Predicted Emission Rates of Toluene from Plot C with 20,000 kg Sludge Applied

REFERENCES

1. As of June, 1986, the Chevron MODT, Appendix P, had been accepted for publication in the International Journal of Environmental Analytical Chemistry under the title "Modified Oven Drying Technique. A New Method to Determine Oil, Water and Solids in Oily Waste." There are currently no plans for publishing the Chevron THF Method, Appendix O.

2. Wetherold, R.G., J.L. Randall, and K.R. Williams. Laboratory Assessment of Potential Hydrocarbon Emissions from Landtreatment of Refinery Oily Sludges. EPA-600/2-84-108, American Petroleum Institute, Washington, D.C., June 1984.

3. U.S. Environmental Protection Agency, Test Methods for Evaluating Waste: Physical Methods. Office of Solid Waste, SW-846 (1982).

4. U.S. Environmental Protection Agency, Characterization of Hazardous Waste Sites, A Methods Manual, Volume III: Available Laboratory Analytical Methods. Office of Research and Development, Draft, 1985.

APPENDIX B

DAILY LOG

Monday, October 8 - The Radian crew arrived on site and prepared for sampling activities. The laboratory trailer was unpacked, analytical instruments calibrated, meteorological station set up, the landfarm plots gridded, and the sampling equipment checked out and set in place.

Tuesday, October 9 - Background measurements made. Representatives from Chevron, U.S. EPA, and Radian Project Director arrive on site.

Wednesday, October 10 - Waste spread at 1030 and sampling begun. Collected all necessary process data and measurements.

Thursday, October 11 - Began sampling prior to 0530 in order to collect data over a range of temperatures. Completed all scheduled testing for the day. Approximately 0.01" rain fell during the evening.

Friday, October 12 - Performed all scheduled sampling and measurements. The plots were tilled at midday.

Saturday, October 13 - Performed all scheduled sampling.

Sunday, October 14 to Sunday October 21 - No sampling activities.

Monday, October 15 - Radian crew arrived on site and prepared equipment for further sampling. Discovered met. equipment had malfunctioned during our absence.

Tuesday, October 23 - Performed all scheduled sampling activities. Representatives from Chevron and U.S. EPA observed the sampling efforts.

Wednesday, October 24 - Sampling continued on schedule with tilling performed at midday. Representative from GCA arrived to observe sampling efforts.

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Thursday, October 25 - Began sampling prior to 0530 to collect data over a range of temperatures. Sampling temporarily suspended about 1000 for two hours to allow final few sampling points to be measured during warmest part of the day.

Friday, October 26 - Sampling continued on schedule with tilling performed at midday.

Saturday, October 27 to Tuesday, November 6 - No sampling activities.

Wednesday, November 7 - Radian crew arrived on site. Set up met. station, checked out analytical instruments, calibrated all thermocouples, and set up sampling equipment at the test plots. A very light rain fell the previous evening, and another 0.02 to 0.03 inches fell Wednesday evening.

Thursday, November 8 - Sampled as scheduled. Low emission rates observed due to the cool weather and wet soil.

Friday, November 9 - Sampling continued on schedule with tilling performed at midday. Representatives from Chevron and SCARB on site.

Saturday, November 10 - Due to low emission rates observed the previous two days, the sampling procedure was modified. Lower sweep air flow rates used to provide a lower detection limit. Discovered actual problem was a dirty GC column in the Byron analyzer and problem was corrected in the mid-afternoon.

Sunday, November 11 - No sampling activities.

Monday, November 12 - Completed all scheduled sampling activities. Final tilling of the plots took place at midday. Equipment was decontaminated and packed for transit.

APPENDIX C

EXAMPLE CALCULATIONS FOR OFF-SITE ANALYTICAL CALCULATIONS OF VARIAN DATA PRINTOUTS

1. Air Sample Concentrations

All sample components were quantitated on the basis of FID carbon response relative to propane or n-hexane. All C_2-C_4 compounds were quantitated against propane and all C_5-C_{11} compounds were quantitated against n-hexane. A quantitative standard of propane and n-hexane (referenced to NBS SRM propane) was analyzed each day. For each analysis, the operator entered the initial and final reservoir pressure, the sample dilution factor and the analysis type (standard or sample). The reservoir volume and standard concentrations were used by the Apple II to calculate sample volumes and response factors. The volume of gas was calculated using the following equation:

$$V_g = \frac{(P_2-P_1)}{14.7}(3.55\ \text{L}) \qquad \text{(C-1)}$$

where:

V_g = volume of sample or standard (L)
P_1 = initial reservoir pressure
P_2 = final reservoir pressure
3.55 L = reservoir volume (L)
14.7 = psi/atmosphere

Quantitative response factors were then calculated for each compound (propane or n-hexane) using the following equation:

$$RF = \frac{\text{area}}{C_s(Vg)} \qquad \text{(C-2)}$$

where:

RF = response factor (area/nL-C)
area = peak area for propane or n-hexane
C_s = concentration of propane or n-hexane (ppbv-C (nL-C/L))
Vg = volume of standard used (L).

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For quantitation of non-halogenated compounds, each peak was first identified, then the peak area was calculated according to the response factor for propane or n-hexane (propane for C_2-C_4 compounds, n-hexane for C_5-C_{11} compounds). All unidentified peaks were quantitated against n-hexane. The calculation to provide sample component quantitation was:

$$C_s = \frac{\text{area}}{RF(Vg)(D_f)} \qquad \text{(C-3)}$$

where:

C_s = concentration of sample component (ppbv-C)
area = area of sample component peak
RF = daily response factor for propane or n-hexane
Vg = volume of sample analyzed (L)
D_f = dilution factor.

The canister dilution factor was calculated as follows:

$$D_f = \frac{P_S - P_I}{P_T + 14.7} \qquad \text{(C-4)}$$

where:

P_S = absolute canister pressure after sample collection,
P_I = initial absolute canister pressure, and
P_T = final absolute pressure after addition of UHP N_2.

Halogenated compounds were quantitated with a Hall electrolytic conductivity detector operated in the halogen mode. Individual response factors for halogenated compounds were generated by analyzing a 17 component certified gas standard. The response factors were calculated by the HP 3390A integrator using the following equation:

$$RF_i = \frac{\text{Amt.}_i}{\text{area}} \qquad \text{(C-5)}$$

where:

RF_i = response factor for compound i (nL-C/area)
$Amt._i$ = amount of compound i (nL-C)
Area = peak area for compound i.

The amount of compound i is determined as follows:

$$Amt._i = V_g \; C_i \tag{C-6}$$

where:

V_g = volume of gas standard (L)
C_i = concentration of compound i in standard (nL-C/L).

For sample components with retention times matching those of the compounds in the calibration standard, concentrations were calculated using the appropriate response factors. Unidentified components were quantitated using an average response factor obtained by computing the arithmetic mean for 16 of the response factors in the calibration standard. Chlorobenzene was excluded due to its atypical response factor. Halogenated sample components were calculated using the following equation:

$$C_i = \frac{(\text{area})(RF_i)}{(V_g)(D_f)} \tag{C-7}$$

where:

C_i = concentration of sample component i (ppbv-C)
area = peak area for compound i
RF_i = response factor for compound i (nL-C/area)
V_g = volume of sample analyzed (L)
D_f = dilution factor.

The volume of sample and dilution factor values were calculated using equations C-1 and C-4, respectively.

The final step in the calculation process was the conversion of concentration units from ppbv-C to $\mu g/m^3$ for each compound reported. This was accomplished by first converting the concentration value to ppbv by using:

$$C_v = \frac{C_c}{a} \qquad \text{(C-8)}$$

where:

C_v = concentration of sample component (ppbv)
C_c = concentration of sample component (nL-C/L)
a = number of carbon atoms per compound (nL-C/nL).

NOTE: 1 ppbv-C = 1 nL-C/L
1 ppbv = 1 nL/L

It was then necessary to convert the value obtained in equation C-8 to number of moles per liter by using:

$$N = C_v \left(\frac{1 \text{ n-mole}}{24.45 \text{ nL}}\right) \qquad \text{(C-9)}$$

where:

N = number of moles per liter (n-mole/L)
C_v = concentration of sample component (nL/L)
$\left(\frac{1 \text{ n-mole}}{24.45 \text{ nL}}\right)$ = derived from approximation of the ideal gas law.

This value is subsequently converted to mass per unit volume:

$$\text{ng/L} = (N)(MW) \qquad \text{(C-10)}$$

or:

$$X_i = 1000\ (N)(MW)$$

where:

N = number of moles per liter (n-mole/L)

MW = molecular weight of compound (ng/n-mole).

X_i = concentration of sample component i (μg/L)

The final step involves conversion of the value obtained from equation C-10 to micrograms per cubic meter:

$$Y_i = X_i \ (1L/0.001 \ m^3) \qquad \text{(C-11)}$$

where:

Y_i = concentration of sample component i (μg/m^3)

X_i = concentration of sample component i (μg/L)

$(1L/0.001 \ m^3)$ = conversion factor.

The entire process for converting the concentration units can be reduced to a single equation:

$$Y_i = [40.9 \times 10^{-3} \ (MW/a)] \ C_c \qquad \text{(C-12)}$$

where:

Y_i = concentration of sample component i (μg/m^3)

MW = molecular weight of component i

a = number of carbon atoms in component i

C_c = concentration of sample component i (nL-C/L)

Example calculations are given in Table C-1 for sample C118, isobutane.

2. Soil Headspace Concentration

The calculations to determine the soil headspace sample component concentration are the same as they are for the air samples except for the determination of volume of sample analyzed. Instead of measuring sample volume with pressure difference of a reservoir, a gas-tight glass sampling syringe was used to inject the proper volume of sample. All other calculation and unit conversions are the same as the air samples.

TABLE C-1. EXAMPLE CALCULATIONS FOR SAMPLE C118, ISOBUTANE

Equation C-1: $$V_g = \frac{(2.13\text{-}1.12 \text{ psi})}{14.7 \text{ psi/atm}} (3.55 \text{ L/atm}) = 0.244 \text{ L}$$

Equation C-2: $$RF = \frac{(39218)}{(147 \text{ ppbv-C})(0.51 \text{ L})} = 522 \text{ area/nL-C}$$

Equation C-3: $$C_s = \frac{(3538)}{(522 \text{ area/nL-C})(0.244 \text{ L})(.3950)} = 70.3 \text{ ppbv-C}$$

Equation C-4: $$D_f = \frac{(-0.39) - (-13.39)}{(18.2 + 14.7)} = 0.3950$$

Equation C-7: $$C_i = \frac{(643{,}340)(1.05\text{x}10^{-5} \text{ nL-C/area})}{(0.244 \text{ L})(0.3950)} = 70.3 \text{ ppbv-C}$$

Equation C-8: $$C_v = (4.40 \text{ nL-C/L})(4 \text{ nL-C/nL}) = 17.6 \text{ nL/L}$$

Equation C-9: $$N = (17.6 \text{ nL/L}) \; \frac{1 \text{ n-mole}}{24.45 \text{ nL}} = 0.719 \text{ n-mole/L}$$

Equation C-10: $$X_i = (1000)(0.719 \text{ n-mole/L})(58.12 \text{ ng/n-mole}) = 41{,}800 \text{ ug/L}$$

Equation C-11: $$Y_i = (41{,}800 \text{ ug/L})(1 \text{ L}/0.001 \text{ m}^3) = 41.8 \text{ ug/m}^3$$

Equation C-12: $$Y_i = \left(40.9 \text{ x } 10^{-3} \, \frac{\text{ug} \cdot \text{n-mole} \cdot \text{L}}{\text{ng} \cdot \text{nL}}\right) \left(\frac{58.12 \text{ ng/n-mole}}{4 \text{ nL-C/nL}}\right) (70.3 \text{ nL-C/L}) = 41.8 \text{ ug/m}^3$$

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3. Liquid Sample Concentration

The quantitation of sample composite in liquid samples varies from that of air samples due to the difference in units used. The quantitative response factors for liquids (RF_L) include a conversion factor which changes the units of the air sample response factor from nL-C to ng-C. Both the n-hexane and the propane response factor is calculated by the same equation:

$$RF_L = \frac{\text{area}}{C_{std}\ (V_g)}\ \frac{24.45\ \text{nL-C}}{12.011\ \text{ng-C}} \qquad \text{(C-13)}$$

$$RF_L = RF\ (2.036)$$

where:

C_{std} = concentration of propane or n-hexane (nL-C/L)
area = peak area for propane or n-hexane standard
V_g = volume of standard used (L)
RF_L = response factor for liquids (area/ng-C)
RF = response factor for air (area/nL-C).

The liquid sample component concentration is calculated using either the propane RF_L (C_2-C_4) or the n-hexane RF_L (C_5-C_{11}). The equation used was:

$$C_s = \frac{\text{area}}{RF_L\ (V_L)} \qquad \text{(C-14)}$$

where:

C_s = concentration of sample component (ng-C/mL)
area = peak area for sample component
RF_L = response factor for liquids (area/ng-C)
V_L = actual volume of sample purged (mL).

For purposes of comparison and reporting, the sample component concentration is converted to the units of mg/L by the following equation:

$$C = C_s \frac{MW}{(12.011)a} \frac{1}{10^3} \qquad \text{(C-15)}$$

where:

C = concentration of sample component in mg/L
C_s = concentration of sample component in ng-C/mL
MW = molecular weight of sample component ng/nmole
12.011 = molecular weight of carbon, ng-C/nmole
a = number of carbon atoms in the sample molecule
$1/10^3$ = conversion from ng/mL to mg/L.

Quantitation of halogenated species in liquid samples was performed using a HECD and 26 component liquid purge standard. Using the external standard method of a HP-3390A integrator, response factors were calculated with the following equation:

$$RF_i = \frac{Amt._i}{area} \qquad \text{(C-16)}$$

where:

RF_i = response factor for species i (ng-L/area)
$Amt._i$ = amount (ng-C) of species i
area = peak area for standard species i.

The amount of species i was determined by the following equation:

$$Amt._i = V_{std} \, C_{std} \qquad \text{(C-17)}$$

where:

V_{std} = volume of liquid purge standard (mL)
C_{std} = concentration of standard (ng-C/mL)

Species identified from the calibration table in the integrator were quantitated using the individual response factor. Unidentified peaks were quantitated using an average response factor obtained by computing the arithmetic mean for the 26 halogenated species. The calculation to provide sample component concentration was:

$$C_s = \frac{\text{area } (RF_i)}{V_L} \qquad \text{(C-18)}$$

where:

C_s = concentration of sample component (ng-L/mL)
RF_i = response factor for sample component or average
V_L = volume of sample purged (mL)

The unit conversion is the same for halogenated species as it is for non-halogenated species.

4. Emission and Mass Rates

Emission rates in units of ($\mu g/m^2$-sec) were calculated as follows:

$$E = \frac{(C)(Q)}{A} \qquad \text{(C-19)}$$

where:

C = canister concentration ($\mu g/m^3$), see equation E-12
Q = flow rate (m^3/sec), see field sampling data sheets
A = area of flux chamber (0.13 m^2)
E = emission rate ($\mu g/m^2$-sec).

The mass rates in units of (Kg/day) were determined as follows:

$$E' = (E)(A')(K) \qquad (C\text{-}20)$$

where:

E = emission rate ($\mu g/m^2$-sec)
A' = area of source (m^2), see Section 4
K = units correction (9.64×10^{-5} sec-Kg/day-μg)
E' = mass rate (Kg/day)

5. Summary Statistics

Values obtained in the calculation of quantities which summarize the concentration and emission rate data are summary statistics. Let X_1, $X_2, \ldots, X_n$ be a set of n individual concentration or emission rate values regarded as a simple random sample from some population. Some basic statistics for a sample of size n are:

- the sample average $\overline{X} = \frac{\sum_{i=1}^{n} X_i}{n}$
- the sample standard deviation $s = \sqrt{\frac{1}{n-1} \sum_{i=1}^{n} (X_i - \overline{X})^2}$
- the sample variance is s^2
- the sample coefficient of variation (also called relative standard deviation) $CV = 100\ s/\overline{X}$

The 95% confidence interval for an average concentration or emission rate is calculated using the following equation:

$$CI = \overline{X} \pm t_{0.025}\ S/\sqrt{n} \qquad (C\text{-}21)$$

where $t_{0.025}$ is obtained from the t-distribution for appropriate degrees of freedom.

The above calculational formulas are used when the total surface area from which the air, soil, and/or liquid samples were taken are assumed to be homogeneous. If, however, different structures of surface areas are known or appear to be present, then alternative statistics must be used which incorporate the size of the area which a measurement value is representing by weighting the individual measurement values:

- the sample weighted average $\bar{X}_w = \dfrac{\sum_{i=1}^{n} w_i X_i}{\sum_{i=1}^{n} W_i}$

- the sample weighted standard deviation $S_w = \dfrac{n \sum_{i=1}^{n} W_i (X_i - \bar{X}_w)^2}{(n-1) \sum_{i=1}^{n} W_i}$

The sample weighted variance, coefficient of variation, and 95% confidence interval are computed as shown above using $\bar{X}_w$ and S_w instead of $\bar{X}$ and S.

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FIELD ID NO:  C063                                                                    DATE SAMPLED:    10/10/84
SAMPLE CONTROL NO:  4173-25                                                           DATE ANALYZED:   10/26/84
SAMPLE TYPE:    CANISTER

---------------------------------------------------------------------------------------------------------------------

                                      CONCENTRATION                                                     CONCENTRATION
      COMPOUND                      (PPBV-C)  (UG/M**3)          COMPOUND                            (PPBV-C)  (UG/M**3)
      --------                      ------------------           --------                            ------------------

PARAFFINS                                                      PARAFFINS (CONT'D)
---------                                                      ------------------
 C-3 VOC                              151.0      86.7           C8 ALKANE                            225.0     131.2
 N-BUTANE                             432.0     256.6           C8 ALKANE                            514.0     299.7
 ISOPENTANE                          1913.0    1129.8           C9 ALKANE                           1037.0     604.6
 N-PENTANE                           1411.0     833.3           C9 ALKANE                           1176.0     685.7
 NEOHEXANE                            129.0      75.8           C8 ALKANE                           2843.0    1657.6
 CYCLOPENTANE                         411.0     235.7           C9 ALKANE                           1143.0     666.4
 2,3-DIMETHYLBUTANE                   626.0     367.8           C10+ ALKANE                         1730.0    1006.9
 ISOHEXANE                           2560.0    1504.2           C10+ ALKANE                         1653.0     962.1
 3-METHYLPENTANE                     1699.0     998.3           C10+ ALKANE                          774.0     450.5
 N-HEXANE                            2682.0    1575.9           C10+ ALKANE                         1184.0     689.1
 METHYLCYCLOPENTANE                  2516.0    1444.1           C10+ ALKANE                          536.0     312.0
 2,4-DIMETHYLPENTANE                  633.0     370.6           C10+ ALKANE                          518.0     301.5
 CYCLOHEXANE                         1178.0     675.0           C10+ ALKANE                         1008.0     586.7
 ISOHEPTANE                          3315.0    1940.8           C10+ ALKANE                          224.0     130.4
 3-METHYLHEXANE                      2126.0    1244.7           C10+ ALKANE                          181.0     105.3
 N-HEPTANE                           3669.0    2148.0           C10+ ALKANE                           79.5      46.3
 METHYLCYCLOHEXANE                   3660.0    2100.0           C10+ ALKANE                          322.0     187.4
 2,5-DIMETHYLHEXANE                  1208.0     705.3
 2,3,4-TRIMETHYLPENTANE               826.0     482.3          OLEFINS
 3-METHYLHEPTANE                     3285.0    1918.5          -------
 2,2,5-TRIMETHYLHEXANE                672.0     443.8           ISOBUTENE + 1-BUTENE                 117.0      67.1
 N-OCTANE                            2832.0    1653.5           2-METHYL-1-BUTENE                    105.0      60.2
 N-NONANE                            5085.0    2964.8           T-2-PENTENE                          165.0      94.6
 N-DECANE                            1558.0     906.8           2-METHYL-2-BUTENE                    254.0     121.4
 N-UNDECANE                           771.0     449.1           1-HEXENE                             144.0      82.7
 C6 ALKANE                             69.0      40.5           2-METHYL-2-PENTENE                   286.0     164.2
 C7 ALKANE                             78.0      45.7           T-2-HEXENE                           268.0     153.8
 C7 ALKANE                           1003.0     587.2           1-METHYLCYCLOHEXENE                  916.0     514.9
 C7 ALKANE                            908.0     531.6           1-OCTENE                             696.0     399.2
 C7 ALKANE                           1458.0     853.6           B-PINENE                            1130.0     629.5
 C7 ALKANE                           2219.0    1299.1           LIMONENE                             542.0     301.9
 C8 ALKANE                            561.0     327.5           C8 ALKENE                           1213.0     695.7
 C9 ALKANE                            497.0     290.2           C9 ALKENE                           1805.0    1035.2
 C9 ALKANE                            673.0     392.9           C10+ ALKENE                          481.0     276.0
 C9 ALKANE                            677.0     395.3
 C8 ALKANE                           2333.0    1362.1          TOTAL AROMATICS
 C9 ALKANE                            686.0     400.5          ---------------
 C9 ALKANE                            301.0     175.5           BENZENE                             1462.0     778.3
 C9 ALKANE                            105.0      61.2           TOLUENE                             5578.0    3001.7

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(A)   ARTIFACT COMPOUND - CONCENTRATION NOT USED IN TOTAL NMHC CALCULATIONS.
(B)   VARIABLE RECOVERY THROUGH DRYING SYSTEM - CONCENTRATIONS NOT USED IN TOTAL NMHC CALCULATIONS.
(C)   CONCENTRATIONS WERE CALCULATED USING VALUES OF 6 FOR THE CARBON NUMBER AND 86 FOR THE MOLECULAR WEIGHT.

  *   UNITS ARE EQUIVALENT TO PPM ASSUMING A DENSITY OF 1.
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FIELD ID NO: CP63
SAMPLE CONTROL NO: 4173-25
SAMPLE TYPE: CANISTER

DATE SAMPLED: 10/10/84
DATE ANALYZED: 10/26/84

COMPOUND	CONCENTRATION (PPBV-C)	CONCENTRATION (UG/M**3)
TOTAL AROMATICS (CONT'D)		
ETHYLBENZENE	1756.0	953.4
P-XYLENE/M-XYLENE	5069.0	2752.2
STYRENE	1586.0	844.1
O-XYLENE	2025.0	1099.5
ISOPROPYLBENZENE	879.0	480.1
N-PROPYLBENZENE	1455.0	794.8
M-ETHYLTOLUENE	1753.9	957.6
1,3,5-TRIMETHYLBENZENE	1507.0	823.2
O-ETHYLTOLUENE	1869.0	1020.9
1,2,4-TRIMETHYLBENZENE	1633.0	892.0
ISOBUTYLBENZENE	356.0	195.4
INDAN	363.0	195.0
INDENE	419.0	221.3
P-DIETHYLBENZENE	346.0	189.9
C9 AROMATIC	753.0	411.3
C10+ AROMATIC	309.0	169.6
C10+ AROMATIC	573.0	314.5
C10+ AROMATIC	728.0	399.6
C10+ AROMATIC	258.0	141.6
C10+ AROMATIC	213.0	116.9
C10+ AROMATIC	240.0	131.7
TOTAL HALOGENATED HC		
METHYLENE CHLORIDE	62.9	218.4
UNIDENTIFIED HALOGENATED HC	14.4	22.2
TOTAL OXYGENATED HC(B)		
1,4-DIOXANE	859.0	773.8
HEXANAL	214.0	146.2
UNIDENTIFIED VOC(C)		
UNIDENTIFIED VOC	1880.0	1102.1
UNIDENTIFIED VOC	319.0	187.0

COMPOUND	CONCENTRATION (PPBV-C)	CONCENTRATION (UG/M**3)
PARAFFINS	72062.5	42093.6
OLEFINS	8122.0	4596.3
TOTAL AROMATICS	31130.0	16884.8
TOTAL HALOGENATED HC	77.3	240.6
TOTAL OXYGENATED HC	1073.0	920.0(B)
UNIDENTIFIED VOC	2199.0	1289.1(C)
TOTAL NMHC	113590.8	65104.2

(A) ARTIFACT COMPOUND - CONCENTRATION NOT USED IN TOTAL NMHC CALCULATIONS.
(B) VARIABLE RECOVERY THROUGH DRYING SYSTEM - CONCENTRATIONS NOT USED IN TOTAL NMHC CALCULATIONS.
(C) CONCENTRATIONS WERE CALCULATED USING VALUES OF 5 FOR THE CARBON NUMBER AND 86 FOR THE MOLECULAR WEIGHT.

FIELD ID NO: C032
SAMPLE CONTROL NO: 4173-2
SAMPLE TYPE: SOLID

DATE SAMPLED: 10/10/84
DATE ANALYZED: 10/29/84

COMPOUND	CONCENTRATION (NG-C/G)	CONCENTRATION (UG/G)*
PARAFFINS		
ISOBUTANE	23841.0	28.8
N-BUTANE	3231.0	3.9
N-PENTANE	24639.0	29.6
NEOHEXANE	14465.0	17.3
CYCLOPENTANE	4164.0	4.9
ISOHEXANE	7279.0	8.7
3-METHYLPENTANE	2442.0	2.9
CYCLOHEXANE	59342.0	69.4
2,2,4-TRIMETHYLPENTANE	38567.0	45.9
N-HEPTANE	55549.0	66.3
METHYLCYCLOHEXANE	61298.0	71.7
2,5-DIMETHYLHEXANE	19972.0	23.8
2,3,4-TRIMETHYLPENTANE	14496.0	17.2
3-METHYLHEPTANE	66473.0	79.1
2,2,5-TRIMETHYLHEXANE	13575.0	18.1
N-OCTANE	63218.0	75.2
N-NONANE	9527.0	11.3
N-DECANE	71182.0	84.3
N-UNDECANE	84493.0	100.0
C5 ALKANE	1449.0	1.7
C6 ALKANE	2327.0	2.8
C6 ALKANE	2647.0	3.2
C6 ALKANE	9959.0	11.9
C7 ALKANE	24499.0	29.2
C7 ALKANE	12772.0	15.2
C7 ALKANE	21621.0	25.8
C7 ALKANE	32455.0	38.7
C7 ALKANE	16690.0	19.9
C7 ALKANE	24488.0	29.2
C8 ALKANE	9229.0	11.0
C8 ALKANE	8378.0	10.0
C8 ALKANE	12253.0	14.6
C8 ALKANE	12592.0	15.0
C8 ALKANE	44705.0	53.2
C8 ALKANE	8457.0	10.0
C8 ALKANE	12750.0	15.1
C9 ALKANE	27434.0	32.6
C9 ALKANE	46585.0	55.3
C10+ ALKANE	19584.0	23.2

COMPOUND	CONCENTRATION (NG-C/G)	CONCENTRATION (UG/G)*
PARAFFINS (CONT'D)		
C10+ ALKANE	160903.0	190.8
C10+ ALKANE	33584.0	39.7
C10+ ALKANE	212292.0	251.6
C10+ ALKANE	129943.0	154.1
C10+ ALKANE	25176.0	29.9
C10+ ALKANE	29721.0	35.2
C10+ ALKANE	58899.0	69.8
C10+ ALKANE	50143.0	59.5
C10+ ALKANE	53824.0	63.8
C10+ ALKANE	46321.0	54.9
C10+ ALKANE	32809.0	38.9
OLEFINS		
ISOBUTENE + 1-BUTENE	1781.0	2.1
2-METHYL-2-BUTENE	58766.0	57.2
T-4-METHYL-2-PENTENE	26565.0	31.1
2-METHYL-1-PENTENE	18963.0	22.2
T-2-HEXENE	15981.0	18.7
C-2-HEXENE	15977.0	18.7
C-3-METHYL-2-PENTENE	16049.0	18.8
CYCLOHEXENE	80534.0	92.8
1-METHYLCYCLOHEXENE	18945.0	21.7
1-OCTENE	16359.0	19.1
C-2-OCTENE	3458.0	4.0
4-NONENE	104018.0	121.5
A-PINENE	38110.0	43.3
LIMONENE	54573.0	61.9
1-UNDECENE	33698.0	39.4
C8 ALKENE	17115.0	20.0
C10+ ALKENE	54580.0	63.8
TOTAL AROMATICS		
BENZENE	90122.0	97.8
TOLUENE	126363.0	138.5
ETHYLBENZENE	50219.0	55.6
P-XYLENE/M-XYLENE	180871.0	200.1
STYRENE	64157.0	69.6

Reproduced from best available copy.

(A) ARTIFACT COMPOUND - CONCENTRATION NOT USED IN TOTAL NMHC CALCULATIONS.
(B) VARIABLE RECOVERY THROUGH DRYING SYSTEM - CONCENTRATIONS NOT USED IN TOTAL NMHC CALCULATIONS.
(C) CONCENTRATIONS WERE CALCULATED USING VALUES OF 6 FOR THE CARBON NUMBER AND 86 FOR THE MOLECULAR WEIGHT.

* UNITS ARE EQUIVALENT TO PPM ASSUMING A DENSITY OF 1.

FIELD ID NO: C039
SAMPLE CONTROL NO: 4173-2
SAMPLE TYPE: SOLID

DATE SAMPLED: 10/19/84
DATE ANALYZED: 10/29/84

COMPOUND	CONCENTRATION (NG-C/G)	CONCENTRATION (UG/G)*
TOTAL AROMATICS (CONT'D)		
O-XYLENE	63221.0	69.9
ISOPROPYLBENZENE	31137.0	34.7
N-PROPYLBENZENE	95201.0	106.0
P-ETHYLTOLUENE	79087.0	88.0
1,3,5-TRIMETHYLBENZENE	99595.0	110.8
O-ETHYLTOLUENE	63786.0	71.0
ISOBUTYLBENZENE	128689.0	143.9
P-ISOPROPYLTOLUENE	45526.0	50.9
INDAN	32451.0	35.5
INDENE	51775.0	55.7
M-DIETHYLBENZENE	43401.0	48.5
N-BUTYLBENZENE	36410.0	40.7
P-DIETHYLBENZENE	47496.0	53.1
NAPHTHALENE	52870.0	56.5
C9 AROMATIC	32675.0	36.4
C9 AROMATIC	38481.0	42.8
C9 AROMATIC	23422.0	26.1
C9 AROMATIC	45922.0	51.1
C9 AROMATIC	59475.0	66.2
C10+ AROMATIC	24139.0	27.0
C10+ AROMATIC	60031.0	67.1
C10+ AROMATIC	44114.0	49.3
C10+ AROMATIC	38564.0	43.1
C10+ AROMATIC	29244.0	32.7
C10+ AROMATIC	116231.0	130.0
C10+ AROMATIC	94077.0	105.2
C10+ AROMATIC	56504.0	63.2
C10+ AROMATIC	95247.0	106.5
C10+ AROMATIC	119679.0	133.8
C10+ AROMATIC	332327.0	371.7
C10+ AROMATIC	58823.0	65.8
C10+ AROMATIC	44731.0	50.0
C10+ AROMATIC	82926.0	92.7
TOTAL HALOGENATED HC		
CHLOROFORM	197.0	2.0
1,2-DICHLOROETHANE	2588.0	10.7

COMPOUND	CONCENTRATION (NG-C/G)	CONCENTRATION (UG/G)*
TOTAL OXYGENATED HC(B)		
ETHANOL	10917.0	20.9
ISOBUTYRALDEHYDE	13499.0	20.3
ISOVALERALDEHYDE	55593.0	79.8
HEXANAL	4682.0	6.5
UNIDENTIFIED VOC(C)		
UNIDENTIFIED VOC	13146.0	15.7
UNIDENTIFIED VOC	12293.0	14.7
UNIDENTIFIED VOC	6069.0	7.2
UNIDENTIFIED VOC	14551.0	17.4
PARAFFINS	1021995.0	2164.6
OLEFINS	575473.0	656.3
TOTAL AROMATICS	2738959.0	3087.8
TOTAL HALOGENATED HC	2785.0	12.6
TOTAL OXYGENATED HC	84691.0	127.5(B)
UNIDENTIFIED VOC	46059.0	55.0(C)
TOTAL NMHC	5225271.0	5976.2

Reproduced from best available copy.

(A) ARTIFACT COMPOUND - CONCENTRATION NOT USED IN TOTAL NMHC CALCULATIONS.
(B) VARIABLE RECOVERY THROUGH DRYING SYSTEM - CONCENTRATIONS NOT USED IN TOTAL NMHC CALCULATIONS.
(C) CONCENTRATIONS WERE CALCULATED USING VALUES OF 5 FOR THE CARBON NUMBER AND 86 FOR THE MOLECULAR WEIGHT.

FIELD ID NO: C474
SAMPLE CONTROL NO: 4235-34
SAMPLE TYPE: LIQUID

DATE SAMPLED: 11/12/84
DATE ANALYZED: 01/08/85

COMPOUND	CONCENTRATION (NG-C/ML)	CONCENTRATION (MG/L)*	COMPOUND	CONCENTRATION (NG-C/ML)	CONCENTRATION (MG/L)*
PARAFFINS					
N-PENTANE	9.6	0.012			
3-METHYLHEPTANE	2.4	0.003			
2,2,5-TRIMETHYLHEXANE	6.2	0.008			
C5 ALKANE	3.5	0.004			
C6 ALKANE	5.1	0.006			
C8 ALKANE	<1.0	<0.001			
C9 ALKANE	1.3	0.002			
C10+ ALKANE	23.9	0.028			
OLEFINS					
ACETONITRILE	3.2	0.004			
1-HEXENE	1.6	0.032			
TOTAL HALOGENATED HC					
TRICHLOROFLUOROMETHANE	2.5	0.029(A)			
1,1-DICHLOROETHYLENE	1.0	0.004			
CHLOROFORM	<1.0	<0.010			
CARBON TETRACHLORIDE	<1.0	<0.013			
TRICHLOROETHYLENE + BROMODICHLOROMETHANE	<1.0	<0.005			
UNIDENTIFIED HALOGENATED HC	<1.0	<0.003			
UNIDENTIFIED VOC(C)					
UNIDENTIFIED VOC	13.4	0.016			
PARAFFINS	51.9	0.063			
OLEFINS	4.8	0.006			
TOTAL HALOGENATED HC	1.0	0.004			
UNIDENTIFIED VOC	13.4	0.016(C)			
TOTAL NMHC	71.1	0.089			

(A) ARTIFACT COMPOUND - CONCENTRATION NOT USED IN TOTAL NMHC CALCULATIONS.
(B) VARIABLE RECOVERY THROUGH DRYING SYSTEM - CONCENTRATIONS NOT USED IN TOTAL NMHC CALCULATIONS.
(C) CONCENTRATIONS WERE CALCULATED USING VALUES OF 6 FOR THE CARBON NUMBER AND 86 FOR THE MOLECULAR WEIGHT.

* UNITS ARE EQUIVALENT TO PPM [illegible]

APPENDIX D
PREDICTED EMISSION RATES FROM MODELING

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                    CHEVRON LANDTREATMENT (EL SEGUNDO)

                    PREDICTIVE MODEL - LANDTREATMENT

              FLUX RATES IN UG/M**2-SEC     (CHEVRON.MODEL)

--------------------------------- SITE=1    CLASS=1    COMPOUND=N-HEPTANE ---------------------------------

   CLASS    PC     COMPOUND       SDATE           T          TO           Q        LOWER95      UPPER95

     1      94     N-HEPTANE     10/10/84        2.0         2.0     15.12520     0.67941     18.51745
     1      94     N-HEPTANE     10/11/84       20.0        20.0      4.78301     0.15611      5.80121
     1      94     N-HEPTANE     10/12/84       40.0        40.0      3.38210     0.21041      4.33386
     1      94     N-HEPTANE     10/12/84       50.5         0.0
     1      94     N-HEPTANE     10/12/84       50.5        50.5      3.01003     0.15470      3.69029
     1      94     N-HEPTANE     10/12/84       60.0         9.5      5.55439     0.22613      7.12940
     1      94     N-HEPTANE     10/13/84       80.0        29.5      3.15201     0.12696      3.73868
     1      94     N-HEPTANE     10/14/84      100.0        49.5      2.43330     0.14661      2.77346
     1      94     N-HEPTANE     10/15/84      120.0        69.5      2.05355     0.09694      2.57428
     1      94     N-HEPTANE     10/15/84      120.5         0.0
     1      94     N-HEPTANE     10/15/84      120.5        70.0      2.04620     0.09573      2.71451
     1      94     N-HEPTANE     10/16/84      140.0        19.5      2.66141     0.09851      3.54817
     1      94     N-HEPTANE     10/16/84      147.5         0.0
     1      94     N-HEPTANE     10/16/84      147.5        27.0      2.26177     0.11472      3.06621
     1      94     N-HEPTANE     10/17/84      160.0        12.5      2.40086     0.14573      2.94982
     1      94     N-HEPTANE     10/17/84      180.0        32.5      1.48895     0.07486      1.68919
     1      94     N-HEPTANE     10/18/84      191.0         0.0
     1      94     N-HEPTANE     10/18/84      191.0        43.5      1.28699     0.06528      1.61325
     1      94     N-HEPTANE     10/18/84      200.0         9.0      1.12949     0.05325      1.33960
     1      94     N-HEPTANE     10/19/84      220.0         0.0
     1      94     N-HEPTANE     10/19/84      220.0        29.0      0.62922     0.03746      0.85235
     1      94     N-HEPTANE     10/20/84      240.0        20.0
     1      94     N-HEPTANE     10/21/84      260.0        40.0
     1      94     N-HEPTANE     10/22/84      280.0        60.0
     1      94     N-HEPTANE     10/22/84      300.0        80.0
     1      94     N-HEPTANE     10/23/84      320.0       100.0
     1      94     N-HEPTANE     10/24/84      338.5         0.0
     1      94     N-HEPTANE     10/24/84      338.5       118.5
     1      94     N-HEPTANE     10/24/84      340.0         1.5
     1      94     N-HEPTANE     10/25/84      360.0        21.5
     1      94     N-HEPTANE     10/26/84      380.0        41.5
     1      94     N-HEPTANE     10/26/84      386.5         0.0
     1      94     N-HEPTANE     10/26/84      386.5        48.0
     1      94     N-HEPTANE     10/27/84      400.0        13.5
     1      94     N-HEPTANE     10/27/84      420.0        33.5
     1      94     N-HEPTANE     10/28/84      440.0        53.5
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                    CHEVRON LANDTREATMENT (EL SEGUNDO)

                    PREDICTIVE MODEL - LANDTREATMENT

            FLUX RATES IN UG/M**2-SEC    (CHEVRON.MODEL)

------------------------------ SITE=1   CLASS=1   COMPOUND=N-HEPTANE ------------------------------

   CLASS   PC   COMPOUND     SDATE        T        TO    Q   LOWER95   UPPER95

     1     94   N-HEPTANE   10/29/84    455.0     0.0
     1     94   N-HEPTANE   10/29/84    455.0    68.5
     1     94   N-HEPTANE   10/29/84    460.0     5.0
     1     94   N-HEPTANE   10/30/84    480.0     0.0
     1     94   N-HEPTANE   10/30/84    480.0    25.0
     1     94   N-HEPTANE   10/31/84    500.0    20.0
     1     94   N-HEPTANE   10/31/84    504.5     0.0
     1     94   N-HEPTANE   10/31/84    504.5    24.5
     1     94   N-HEPTANE   11/01/84    520.0    15.5
     1     94   N-HEPTANE   11/01/84    528.0     0.0
     1     94   N-HEPTANE   11/01/84    528.0    23.5
     1     94   N-HEPTANE   11/01/84    540.0    12.0
     1     94   N-HEPTANE   11/02/84    552.0     0.0
     1     94   N-HEPTANE   11/02/84    552.0    24.0
     1     94   N-HEPTANE   11/02/84    560.0     8.0
     1     94   N-HEPTANE   11/03/84    580.0    28.0
     1     94   N-HEPTANE   11/04/84    600.0    48.0
     1     94   N-HEPTANE   11/05/84    620.0    68.0
     1     94   N-HEPTANE   11/05/84    628.0     0.0
     1     94   N-HEPTANE   11/05/84    628.0    76.0
     1     94   N-HEPTANE   11/06/84    640.0    12.0
     1     94   N-HEPTANE   11/06/84    660.0    32.0
     1     94   N-HEPTANE   11/07/84    680.0    52.0
     1     94   N-HEPTANE   11/08/84    700.0    72.0
     1     94   N-HEPTANE   11/09/84    720.0    92.0
     1     94   N-HEPTANE   11/09/84    722.5     0.0
     1     94   N-HEPTANE   11/09/84    722.5    94.5
     1     94   N-HEPTANE   11/10/84    740.0    17.5
     1     94   N-HEPTANE   11/11/84    760.0    37.5
     1     94   N-HEPTANE   11/11/84    780.0    57.5
     1     94   N-HEPTANE   11/12/84    793.0     0.0
     1     94   N-HEPTANE   11/12/84    793.0    70.5
     1     94   N-HEPTANE   11/12/84    800.0     7.0
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                    CHEVRON LANDTREATMENT (EL SEGUNDO)

                      PREDICTIVE MODEL - LANDTREATMENT

               FLUX RATES IN UG/M**2-SEC     (CHEVRON.MODEL)

---------------------------- SITE=1   CLASS=1   COMPOUND=3-METHYLHEPTANE ------------------------------

 CLASS    PC      COMPOUND          SDATE        T        TO         Q        LOWER95     UPPER95

   1      113   3-METHYLHEPTANE   10/10/84      2.0       2.0    11.80230    0.46711    13.19060
   1      113   3-METHYLHEPTANE   10/11/84     20.0      20.0     3.73222    0.13120     4.95039
   1      113   3-METHYLHEPTANE   10/12/84     40.0      40.0     2.63907    0.14428     3.19527
   1      113   3-METHYLHEPTANE   10/12/84     50.5       0.0
   1      113   3-METHYLHEPTANE   10/12/84     50.5      50.5     2.34875    0.08226     3.06456
   1      113   3-METHYLHEPTANE   10/12/84     60.0       9.5     4.77515    0.15356     6.14105
   1      113   3-METHYLHEPTANE   10/13/84     80.0      29.5     2.70980    0.09568     3.56725
   1      113   3-METHYLHEPTANE   10/14/84    100.0      49.5     2.09192    0.07938     2.71150
   1      113   3-METHYLHEPTANE   10/15/84    120.0      69.5     1.76545    0.10214     2.31385
   1      113   3-METHYLHEPTANE   10/15/84    120.5       0.0
   1      113   3-METHYLHEPTANE   10/15/84    120.5      70.0     1.75914    0.06852     2.17370
   1      113   3-METHYLHEPTANE   10/16/84    140.0      19.5     2.79454    0.12372     3.49013
   1      113   3-METHYLHEPTANE   10/16/84    147.5       0.0
   1      113   3-METHYLHEPTANE   10/16/84    147.5      27.0     2.37490    0.09451     2.66293
   1      113   3-METHYLHEPTANE   10/17/84    160.0      12.5     3.08264    0.14911     3.63488
   1      113   3-METHYLHEPTANE   10/17/84    180.0      32.5     1.91177    0.06743     2.35120
   1      113   3-METHYLHEPTANE   10/18/84    191.0       0.0
   1      113   3-METHYLHEPTANE   10/18/84    191.0      43.5     1.65247    0.09055     2.01223
   1      113   3-METHYLHEPTANE   10/18/84    200.0       9.0     3.00421    0.12596     3.83746
   1      113   3-METHYLHEPTANE   10/19/84    220.0       0.0
   1      113   3-METHYLHEPTANE   10/19/84    220.0      29.0     1.67360    0.08453     2.11730
   1      113   3-METHYLHEPTANE   10/20/84    240.0      20.0     1.67138    0.09176     1.97887
   1      113   3-METHYLHEPTANE   10/21/84    260.0      40.0     1.18185    0.04455     1.36229
   1      113   3-METHYLHEPTANE   10/22/84    280.0      60.0     0.96497    0.04430     1.16687
   1      113   3-METHYLHEPTANE   10/22/84    300.0      80.0     0.83569    0.04322     1.06102
   1      113   3-METHYLHEPTANE   10/23/84    320.0     100.0     0.74747    0.03119     0.87875
   1      113   3-METHYLHEPTANE   10/24/84    338.5       0.0
   1      113   3-METHYLHEPTANE   10/24/84    338.5     118.5     0.68664    0.03172     0.86607
   1      113   3-METHYLHEPTANE   10/24/84    340.0       1.5     2.96435    0.18027     4.07889
   1      113   3-METHYLHEPTANE   10/25/84    360.0      21.5     0.78827    0.04493     0.95029
   1      113   3-METHYLHEPTANE   10/26/84    380.0      41.5     0.56738    0.02826     0.63283
   1      113   3-METHYLHEPTANE   10/26/84    386.5       0.0
   1      113   3-METHYLHEPTANE   10/26/84    386.5      48.0     0.52756    0.02924     0.65149
   1      113   3-METHYLHEPTANE   10/27/84    400.0      13.5     0.09788    0.02134     0.36097
   1      113   3-METHYLHEPTANE   10/27/84    420.0      33.5     0.06213    0.01141     0.26418
   1      113   3-METHYLHEPTANE   10/28/84    440.0      53.5     0.04917    0.00917     0.18770
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                         CHEVRON LANDTREATMENT (EL SEGUNDO)

                         PREDICTIVE MODEL - LANDTREATMENT

                   FLUX RATES IN UG/M**2-SEC    (CHEVRON.MODEL)

----------------------------- SITE=1   CLASS=1   COMPOUND=3-METHYLHEPTANE -----------------------------

  CLASS    PC      COMPOUND          SDATE        T        TO        Q        LOWER95    UPPER95

    1      113   3-METHYLHEPTANE   10/29/84    455.0      0.0
    1      113   3-METHYLHEPTANE   10/29/84    455.0     68.5   0.04345    0.00714    0.17130
    1      113   3-METHYLHEPTANE   10/29/84    460.0      5.0
    1      113   3-METHYLHEPTANE   10/30/84    480.0      0.0
    1      113   3-METHYLHEPTANE   10/30/84    480.0     25.0
    1      113   3-METHYLHEPTANE   10/31/84    500.0     20.0
    1      113   3-METHYLHEPTANE   10/31/84    504.5      0.0
    1      113   3-METHYLHEPTANE   10/31/84    504.5     24.5
    1      113   3-METHYLHEPTANE   11/01/84    520.0     15.5
    1      113   3-METHYLHEPTANE   11/01/84    528.0      0.0
    1      113   3-METHYLHEPTANE   11/01/84    528.0     23.5
    1      113   3-METHYLHEPTANE   11/01/84    540.0     12.0
    1      113   3-METHYLHEPTANE   11/02/84    552.0      0.0
    1      113   3-METHYLHEPTANE   11/02/84    552.0     24.0
    1      113   3-METHYLHEPTANE   11/02/84    560.0      8.0
    1      113   3-METHYLHEPTANE   11/03/84    580.0     28.0
    1      113   3-METHYLHEPTANE   11/04/84    600.0     48.0
    1      113   3-METHYLHEPTANE   11/05/84    620.0     68.0
    1      113   3-METHYLHEPTANE   11/05/84    628.0      0.0
    1      113   3-METHYLHEPTANE   11/05/84    628.0     76.0
    1      113   3-METHYLHEPTANE   11/06/84    640.0     12.0
    1      113   3-METHYLHEPTANE   11/06/84    660.0     32.0
    1      113   3-METHYLHEPTANE   11/07/84    680.0     52.0
    1      113   3-METHYLHEPTANE   11/08/84    700.0     72.0
    1      113   3-METHYLHEPTANE   11/09/84    720.0     92.0
    1      113   3-METHYLHEPTANE   11/09/84    722.5      0.0
    1      113   3-METHYLHEPTANE   11/09/84    722.5     94.5
    1      113   3-METHYLHEPTANE   11/10/84    740.0     17.5
    1      113   3-METHYLHEPTANE   11/11/84    760.0     37.5
    1      113   3-METHYLHEPTANE   11/11/84    780.0     57.5
    1      113   3-METHYLHEPTANE   11/12/84    793.0      0.0
    1      113   3-METHYLHEPTANE   11/12/84    793.0     70.5
    1      113   3-METHYLHEPTANE   11/12/84    800.0      7.0
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                    CHEVRON LANDTREATMENT (EL SEGUNDO)

                     PREDICTIVE MODEL - LANDTREATMENT

               FLUX RATES IN UG/M**2-SEC     (CHEVRON.MODEL)

-------------------------------- SITE=1    CLASS=1    COMPOUND=N-NONANE ------------------------------------

   CLASS     PC     COMPOUND      SDATE          T         TO          Q       LOWER95     UPPER95

     1       132    N-NONANE     10/10/84       2.0       2.0     2.76225     0.17462     3.46035
     1       132    N-NONANE     10/11/84      20.0      20.0     0.87350     0.05272     1.02220
     1       132    N-NONANE     10/12/84      40.0      40.0     0.61766     0.03666     0.75836
     1       132    N-NONANE     10/12/84      50.5       0.0
     1       132    N-NONANE     10/12/84      50.5      50.5     0.54971     0.02909     0.76241
     1       132    N-NONANE     10/12/84      60.0       9.5     1.19913     0.06467     1.61034
     1       132    N-NONANE     10/13/84      80.0      29.5     0.68048     0.03059     0.80848
     1       132    N-NONANE     10/14/84     100.0      49.5     0.52532     0.03630     0.66870
     1       132    N-NONANE     10/15/84     120.0      69.5     0.44334     0.01755     0.50543
     1       132    N-NONANE     10/15/84     120.5       0.0
     1       132    N-NONANE     10/15/84     120.5      70.0     0.44175     0.02143     0.47046
     1       132    N-NONANE     10/16/84     140.0      19.5     0.78046     0.04194     0.86319
     1       132    N-NONANE     10/16/84     147.5       0.0
     1       132    N-NONANE     10/16/84     147.5      27.0     0.66327     0.03756     0.78381
     1       132    N-NONANE     10/17/84     160.0      12.5     0.93149     0.05307     1.22115
     1       132    N-NONANE     10/17/84     180.0      32.5     0.57768     0.03582     0.61707
     1       132    N-NONANE     10/18/84     191.0       0.0
     1       132    N-NONANE     10/18/84     191.0      43.5     0.49933     0.03748     0.61951
     1       132    N-NONANE     10/18/84     200.0       9.0     1.03247     0.06730     1.29616
     1       132    N-NONANE     10/19/84     220.0       0.0
     1       132    N-NONANE     10/19/84     220.0      29.0     0.57517     0.03819     0.69441
     1       132    N-NONANE     10/20/84     240.0      20.0     0.65699     0.04480     0.73234
     1       132    N-NONANE     10/21/84     260.0      40.0     0.46456     0.02901     0.55816
     1       132    N-NONANE     10/22/84     280.0      60.0     0.37931     0.02464     0.47760
     1       132    N-NONANE     10/22/84     300.0      80.0     0.32849     0.02650     0.38291
     1       132    N-NONANE     10/23/84     320.0     100.0     0.29361     0.01833     0.36223
     1       132    N-NONANE     10/24/84     338.5       0.0
     1       132    N-NONANE     10/24/84     338.5     118.5     0.26991     0.01559     0.29660
     1       132    N-NONANE     10/24/84     340.0       1.5     2.12748     0.12816     2.93067
     1       132    N-NONANE     10/25/84     360.0      21.5     0.56194     0.02599     0.67453
     1       132    N-NONANE     10/26/84     380.0      41.5     0.40447     0.02354     0.53377
     1       132    N-NONANE     10/26/84     386.5       0.0
     1       132    N-NONANE     10/26/84     386.5      48.0     0.37609     0.01723     0.43059
     1       132    N-NONANE     10/27/84     400.0      13.5     0.65256     0.03344     0.81126
     1       132    N-NONANE     10/27/84     420.0      33.5     0.41425     0.02989     0.52612
     1       132    N-NONANE     10/28/84     440.0      53.5     0.32780     0.02436     0.36589
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                         CHEVRON LANDTREATMENT (EL SEGUNDO)

                          PREDICTIVE MODEL - LANDTREATMENT

                      FLUX RATES IN UG/M**2-SEC    (CHEVRON.MODEL)

-------------------------------- SITE=1    CLASS=1    COMPOUND=N-NONANE -----------------------------------

      CLASS      PC       COMPOUND        SDATE          T          TO         Q        LOWER95     UPPER95

        1       132       N-NONANE       10/29/84      455.0        0.0
        1       132       N-NONANE       10/29/84      455.0       68.5      0.28970     0.02151     0.36106
        1       132       N-NONANE       10/29/84      460.0        5.0      0.95970     0.06901     1.19452
        1       132       N-NONANE       10/30/84      480.0        0.0
        1       132       N-NONANE       10/30/84      480.0       25.0      0.42919     0.03679     0.48407
        1       132       N-NONANE       10/31/84      500.0       20.0      0.44647     0.02874     0.54377
        1       132       N-NONANE       10/31/84      504.5        0.0
        1       132       N-NONANE       10/31/84      504.5       24.5      0.40339     0.02373     0.50178
        1       132       N-NONANE       11/01/84      520.0       15.5      0.46953     0.03267     0.51997
        1       132       N-NONANE       11/01/84      528.0        0.0
        1       132       N-NONANE       11/01/84      528.0       23.5      0.38133     0.02163     0.44287
        1       132       N-NONANE       11/01/84      540.0       12.0      0.49165     0.05747     0.55437
        1       132       N-NONANE       11/02/84      552.0        0.0
        1       132       N-NONANE       11/02/84      552.0       24.0      0.34765     0.02049     0.40935
        1       132       N-NONANE       11/02/84      560.0        8.0      0.54998     0.03963     0.64998
        1       132       N-NONANE       11/03/84      580.0       28.0      0.29397     0.01949     0.36476
        1       132       N-NONANE       11/04/84      600.0       48.0      0.22453     0.01863     0.27068
        1       132       N-NONANE       11/05/84      620.0       68.0      0.18864     0.01284     0.23688
        1       132       N-NONANE       11/05/84      628.0        0.0
        1       132       N-NONANE       11/05/84      628.0       76.0      0.17844     0.00928     0.21524
        1       132       N-NONANE       11/06/84      640.0       12.0      0.36948     0.02701     0.46792
        1       132       N-NONANE       11/06/84      660.0       32.0      0.22626     0.01493     0.26475
        1       132       N-NONANE       11/07/84      680.0       52.0      0.17749     0.01038     0.19900
        1       132       N-NONANE       11/08/84      700.0       72.0      0.15084     0.01168     0.18813
        1       132       N-NONANE       11/09/84      720.0       92.0      0.13344     0.00644     0.16532
        1       132       N-NONANE       11/09/84      722.5        0.0
        1       132       N-NONANE       11/09/84      722.5       94.5      0.13166     0.00901     0.15946
        1       132       N-NONANE       11/10/84      740.0       17.5      0.22942     0.01570     0.27653
        1       132       N-NONANE       11/11/84      760.0       37.5      0.15673     0.01114     0.20418
        1       132       N-NONANE       11/11/84      780.0       57.5      0.12657     0.00517     0.14888
        1       132       N-NONANE       11/12/84      793.0        0.0
        1       132       N-NONANE       11/12/84      793.0       70.5      0.11430     0.00658     0.12802
        1       132       N-NONANE       11/12/84      800.0        7.0      0.25542     0.01591     0.30971
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                         CHEVRON LANDTREATMENT (EL SEGUNDO)

                         PREDICTIVE MODEL - LANDTREATMENT

                    FLUX RATES IN UG/M**2-SEC     (CHEVRON.MODEL)

------------------------------- SITE=1    CLASS=2    COMPOUND=1-OCTENE ------------------------------------

   CLASS      PC      COMPOUND       SDATE            T         TO         Q        LOWER95      UPPER95

     2       117     1-OCTENE     10/10/84          2.0        2.0     2.66358     0.21770     2.97690
     2       117     1-OCTENE     10/11/84         20.0       20.0     0.84230     0.05896     1.11722
     2       117     1-OCTENE     10/12/84         40.0       40.0     0.59560     0.05108     0.72112
     2       117     1-OCTENE     10/12/84         50.5        0.0
     2       117     1-OCTENE     10/12/84         50.5       50.5     0.53007     0.03834     0.69162
     2       117     1-OCTENE     10/12/84         60.0        9.5     1.08344     0.07195     1.39335
     2       117     1-OCTENE     10/13/84         80.0       29.5     0.61483     0.04483     0.80938
     2       117     1-OCTENE     10/14/84        100.0       49.5     0.47464     0.03682     0.61522
     2       117     1-OCTENE     10/15/84        120.0       69.5     0.40057     0.04231     0.52499
     2       117     1-OCTENE     10/15/84        120.5        0.0
     2       117     1-OCTENE     10/15/84        120.5       70.0     0.39913     0.03037     0.49319
     2       117     1-OCTENE     10/16/84        140.0       19.5     0.63974     0.05734     0.79898
     2       117     1-OCTENE     10/16/84        147.5        0.0
     2       117     1-OCTENE     10/16/84        147.5       27.0     0.54368     0.04346     0.60962
     2       117     1-OCTENE     10/17/84        160.0       12.5     0.71077     0.07100     0.83810
     2       117     1-OCTENE     10/17/84        180.0       32.5     0.44080     0.03207     0.54212
     2       117     1-OCTENE     10/18/84        191.0        0.0
     2       117     1-OCTENE     10/18/84        191.0       43.5     0.38101     0.03833     0.46397
     2       117     1-OCTENE     10/18/84        200.0        9.0     0.70190     0.05871     0.89658
     2       117     1-OCTENE     10/19/84        220.0        0.0
     2       117     1-OCTENE     10/19/84        220.0       29.0     0.39102     0.03940     0.49469
     2       117     1-OCTENE     10/20/84        240.0       20.0     0.39668     0.04497     0.46966
     2       117     1-OCTENE     10/21/84        260.0       40.0     0.28050     0.02183     0.32332
     2       117     1-OCTENE     10/22/84        280.0       60.0     0.22903     0.02171     0.27694
     2       117     1-OCTENE     10/22/84        300.0       80.0     0.19834     0.02014     0.25182
     2       117     1-OCTENE     10/23/84        320.0      100.0     0.17740     0.01298     0.20856
     2       117     1-OCTENE     10/24/84        338.5        0.0
     2       117     1-OCTENE     10/24/84        338.5      118.5     0.16297     0.01554     0.20555
     2       117     1-OCTENE     10/24/84        340.0        1.5     0.79815     0.09956     1.09088
     2       117     1-OCTENE     10/25/84        360.0       21.5     0.21082     0.02452     0.25415
     2       117     1-OCTENE     10/26/84        380.0       41.5     0.15174     0.01497     0.16925
     2       117     1-OCTENE     10/26/84        386.5        0.0
     2       117     1-OCTENE     10/26/84        386.5       48.0     0.14109     0.01468     0.17424
     2       117     1-OCTENE     10/27/84        400.0       13.5     0.11769     0.01956     0.16623
     2       117     1-OCTENE     10/27/84        420.0       33.5     0.07471     0.01098     0.12313
     2       117     1-OCTENE     10/28/84        440.0       53.5     0.05912     0.00916     0.08748
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                    CHEVRON LANDTREATMENT (EL SEGUNDO)

                     PREDICTIVE MODEL - LANDTREATMENT

                FLUX RATES IN UG/M**2-SEC     (CHEVRON.MODEL)

------------------------------- SITE=1   CLASS=2   COMPOUND=1-OCTENE -----------------------------------

    CLASS     PC     COMPOUND      SDATE        T        TO         Q        LOWER95      UPPER95

      2       117    1-OCTENE    10/29/84    455.0      0.0
      2       117    1-OCTENE    10/29/84    455.0     68.5     0.05225     0.00688      0.07984
      2       117    1-OCTENE    10/29/84    460.0      5.0
      2       117    1-OCTENE    10/30/84    480.0      0.0
      2       117    1-OCTENE    10/30/84    480.0     25.0
      2       117    1-OCTENE    10/31/84    500.0     20.0
      2       117    1-OCTENE    10/31/84    504.5      0.0
      2       117    1-OCTENE    10/31/84    504.5     24.5
      2       117    1-OCTENE    11/01/84    520.0     15.5
      2       117    1-OCTENE    11/01/84    528.0      0.0
      2       117    1-OCTENE    11/01/84    528.0     23.5
      2       117    1-OCTENE    11/01/84    540.0     12.0
      2       117    1-OCTENE    11/02/84    552.0      0.0
      2       117    1-OCTENE    11/02/84    552.0     24.0
      2       117    1-OCTENE    11/02/84    560.0      8.0
      2       117    1-OCTENE    11/03/84    580.0     28.0
      2       117    1-OCTENE    11/04/84    600.0     48.0
      2       117    1-OCTENE    11/05/84    620.0     68.0
      2       117    1-OCTENE    11/05/84    628.0      0.0
      2       117    1-OCTENE    11/05/84    628.0     76.0
      2       117    1-OCTENE    11/06/84    640.0     12.0
      2       117    1-OCTENE    11/06/84    660.0     32.0
      2       117    1-OCTENE    11/07/84    680.0     52.0
      2       117    1-OCTENE    11/08/84    700.0     72.0
      2       117    1-OCTENE    11/09/84    720.0     92.0
      2       117    1-OCTENE    11/09/84    722.5      0.0
      2       117    1-OCTENE    11/09/84    722.5     94.5
      2       117    1-OCTENE    11/10/84    740.0     17.5
      2       117    1-OCTENE    11/11/84    760.0     37.5
      2       117    1-OCTENE    11/11/84    780.0     57.5
      2       117    1-OCTENE    11/12/84    793.0      0.0
      2       117    1-OCTENE    11/12/84    793.0     70.5
      2       117    1-OCTENE    11/12/84    800.0      7.0
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                              CHEVRON LANDTREATMENT (EL SEGUNDO)

                              PREDICTIVE MODEL - LANDTREATMENT

                        FLUX RATES IN UG/M**2-SEC     (CHEVRON.MODEL)

----------------------------- SITE=1   CLASS=2   COMPOUND=B-PINENE ------------------------------------

    CLASS     PC     COMPOUND      SDATE          T        TO         Q      LOWER95    UPPER95

      2      144     B-PINENE    10/10/84       2.0       2.0    4.27321    0.16863    5.23160
      2      144     B-PINENE    10/11/84      20.0      20.0    1.35131    0.03875    1.63897
      2      144     B-PINENE    10/12/84      40.0      40.0    0.95552    0.05222    1.22441
      2      144     B-PINENE    10/12/84      50.5       0.0
      2      144     B-PINENE    10/12/84      50.5      50.5    0.85040    0.03840    1.04259
      2      144     B-PINENE    10/12/84      60.0       9.5    1.88228    0.06408    2.41602
      2      144     B-PINENE    10/13/84      80.0      29.5    1.06816    0.03670    1.26697
      2      144     B-PINENE    10/14/84     100.0      49.5    0.82460    0.03769    0.93988
      2      144     B-PINENE    10/15/84     120.0      69.5    0.69591    0.02886    0.87238
      2      144     B-PINENE    10/15/84     120.5       0.0
      2      144     B-PINENE    10/15/84     120.5      70.0    0.69342    0.02840    0.91990
      2      144     B-PINENE    10/16/84     140.0      19.5    1.24906    0.04062    1.66524
      2      144     B-PINENE    10/16/84     147.5       0.0
      2      144     B-PINENE    10/16/84     147.5      27.0    1.06150    0.03452    1.43905
      2      144     B-PINENE    10/17/84     160.0      12.5    1.51031    0.05615    1.85564
      2      144     B-PINENE    10/17/84     180.0      32.5    0.93665    0.03535    1.06262
      2      144     B-PINENE    10/18/84     191.0       0.0
      2      144     B-PINENE    10/18/84     191.0      43.5    0.80961    0.02697    1.01484
      2      144     B-PINENE    10/18/84     200.0       9.0    1.70508    0.06288    2.02225
      2      144     B-PINENE    10/19/84     220.0       0.0
      2      144     B-PINENE    10/19/84     220.0      29.0    0.94987    0.03590    1.28670
      2      144     B-PINENE    10/20/84     240.0      20.0    1.10294    0.05725    1.34459
      2      144     B-PINENE    10/21/84     260.0      40.0    0.77990    0.02635    0.86182
      2      144     B-PINENE    10/22/84     280.0      60.0    0.63678    0.02862    0.76741
      2      144     B-PINENE    10/22/84     300.0      80.0    0.55147    0.01864    0.68689
      2      144     B-PINENE    10/23/84     320.0     100.0    0.49325    0.02528    0.65429
      2      144     B-PINENE    10/24/84     338.5       0.0
      2      144     B-PINENE    10/24/84     338.5     118.5    0.45311    0.02194    0.57622
      2      144     B-PINENE    10/24/84     340.0       1.5    3.71939    0.16104    4.33700
      2      144     B-PINENE    10/25/84     360.0      21.5    0.98242    0.04056    1.16421
      2      144     B-PINENE    10/26/84     380.0      41.5    0.70712    0.03415    0.81742
      2      144     B-PINENE    10/26/84     386.5       0.0
      2      144     B-PINENE    10/26/84     386.5      49.0    0.65750    0.02695    0.85679
      2      144     B-PINENE    10/27/84     400.0      13.5    1.17528    0.04642    1.52006
      2      144     B-PINENE    10/27/84     420.0      33.5    0.74608    0.02962    0.83145
      2      144     B-PINENE    10/28/84     440.0      53.5    0.59038    0.02766    0.67792
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                          CHEVRON LANDTREATMENT (EL SEGUNDO)

                           PREDICTIVE MODEL - LANDTREATMENT

                    FLUX RATES IN UG/M**2-SEC    (CHEVRON.MODEL)

-------------------------------- SITE=1   CLASS=2   COMPOUND=B-PINENE ------------------------------------

     CLASS    PC    COMPOUND     SDATE        T        TO        Q         LOWER95     UPPER95

       2     144    B-PINENE    10/29/84    455.0     0.0
       2     144    B-PINENE    10/29/84    455.0    68.5    0.52175     0.03069     0.67446
       2     144    B-PINENE    10/29/84    460.0     5.0    1.80362     0.08506     2.14035
       2     144    B-PINENE    10/30/84    480.0     0.0
       2     144    B-PINENE    10/30/84    480.0    25.0    0.80660     0.02567     0.91833
       2     144    B-PINENE    10/31/84    500.0    20.0    0.86375     0.03474     1.04980
       2     144    B-PINENE    10/31/84    504.5     0.0
       2     144    B-PINENE    10/31/84    504.5    24.5    0.78040     0.03766     0.98989
       2     144    B-PINENE    11/01/84    520.0    15.5    0.93832     0.04877     1.15030
       2     144    B-PINENE    11/01/84    528.0     0.0
       2     144    B-PINENE    11/01/84    528.0    23.5    0.76205     0.02931     0.85842
       2     144    B-PINENE    11/01/84    540.0    12.0    1.01871     0.04834     1.22887
       2     144    B-PINENE    11/02/84    552.0     0.0
       2     144    B-PINENE    11/02/84    552.0    24.0    0.72034     0.03561     0.80687
       2     144    B-PINENE    11/02/84    560.0     8.0    1.18853     0.05585     1.36014
       2     144    B-PINENE    11/03/84    580.0    28.0    0.63530     0.02933     0.71632
       2     144    B-PINENE    11/04/84    600.0    48.0    0.48522     0.02166     0.63728
       2     144    B-PINENE    11/05/84    620.0    68.0    0.40766     0.01847     0.54652
       2     144    B-PINENE    11/05/84    628.0     0.0
       2     144    B-PINENE    11/05/84    628.0    76.0    0.38561     0.01456     0.46458
       2     144    B-PINENE    11/06/84    640.0    12.0    0.88259     0.03983     1.04103
       2     144    B-PINENE    11/06/84    660.0    32.0    0.54047     0.01784     0.70501
       2     144    B-PINENE    11/07/84    680.0    52.0    0.42398     0.01893     0.48671
       2     144    B-PINENE    11/08/84    700.0    72.0    0.36032     0.01461     0.43770
       2     144    B-PINENE    11/09/84    720.0    92.0    0.31875     0.01207     0.42037
       2     144    B-PINENE    11/09/84    722.5     0.0
       2     144    B-PINENE    11/09/84    722.5    94.5    0.31451     0.01431     0.38910
       2     144    B-PINENE    11/10/84    740.0    17.5    0.64881     0.02799     0.76423
       2     144    B-PINENE    11/11/84    760.0    37.5    0.44322     0.02076     0.50057
       2     144    B-PINENE    11/11/84    780.0    57.5    0.35793     0.01967     0.43599
       2     144    B-PINENE    11/12/84    793.0     0.0
       2     144    B-PINENE    11/12/84    793.0    70.5    0.32325     0.01039     0.42470
       2     144    B-PINENE    11/12/84    800.0     7.0    0.91400     0.03007     1.04980
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                    CHEVRON LANDTREATMENT (EL SEGUNDO)

                    PREDICTIVE MODEL - LANDTREATMENT

             FLUX RATES IN UG/M**2-SEC     (CHEVRON.MODEL)

------------------------------ SITE=1   CLASS=2   COMPOUND=LIMONENE ------------------------------

   CLASS     PC      COMPOUND      SDATE           T        TO         Q       LOWER95     UPPER95

     2      157      LIMONENE     10/10/84       2.0       2.0     2.41524     0.14395     3.02564
     2      157      LIMONENE     10/11/84      20.0      20.0     0.76377     0.04346     0.89378
     2      157      LIMONENE     10/12/84      40.0      40.0     0.54006     0.03025     0.66309
     2      157      LIMONENE     10/12/84      50.5       0.0
     2      157      LIMONENE     10/12/84      50.5      50.5     0.48065     0.02398     0.66663
     2      157      LIMONENE     10/12/84      60.0       9.5     1.06208     0.05400     1.42629
     2      157      LIMONENE     10/13/84      80.0      29.5     0.60271     0.02554     0.71608
     2      157      LIMONENE     10/14/84     100.0      49.5     0.46528     0.02992     0.59227
     2      157      LIMONENE     10/15/84     120.0      69.5     0.39267     0.01447     0.44766
     2      157      LIMONENE     10/15/84     120.5       0.0
     2      157      LIMONENE     10/15/84     120.5      70.0     0.39126     0.01790     0.41669
     2      157      LIMONENE     10/16/84     140.0      19.5     0.70823     0.03563     0.79579
     2      157      LIMONENE     10/16/84     147.5       0.0
     2      157      LIMONENE     10/16/84     147.5      27.0     0.59763     0.03191     0.70624
     2      157      LIMONENE     10/17/84     160.0      12.5     0.84906     0.04561     1.11309
     2      157      LIMONENE     10/17/84     180.0      32.5     0.52657     0.03004     0.56247
     2      157      LIMONENE     10/18/84     191.0       0.0
     2      157      LIMONENE     10/18/84     191.0      43.5     0.45515     0.03090     0.56469
     2      157      LIMONENE     10/18/84     200.0       9.0     0.95661     0.05601     1.20092
     2      157      LIMONENE     10/19/84     220.0       0.0
     2      157      LIMONENE     10/19/84     220.0      29.0     0.53291     0.03336     0.64338
     2      157      LIMONENE     10/20/84     240.0      20.0     0.61768     0.03971     0.68853
     2      157      LIMONENE     10/21/84     260.0      40.0     0.43677     0.02528     0.52477
     2      157      LIMONENE     10/22/84     280.0      60.0     0.35662     0.02184     0.44903
     2      157      LIMONENE     10/22/84     300.0      80.0     0.30884     0.02335     0.36000
     2      157      LIMONENE     10/23/84     320.0     100.0     0.27624     0.01625     0.34056
     2      157      LIMONENE     10/24/84     338.5       0.0
     2      157      LIMONENE     10/24/84     338.5     118.5     0.25376     0.01382     0.27885
     2      157      LIMONENE     10/24/84     340.0       1.5     2.07410     0.12252     2.85713
     2      157      LIMONENE     10/25/84     360.0      21.5     0.54784     0.02143     0.65761
     2      157      LIMONENE     10/26/84     380.0      41.5     0.39432     0.02164     0.52038
     2      157      LIMONENE     10/26/84     386.5       0.0
     2      157      LIMONENE     10/26/84     386.5      48.0     0.36665     0.01600     0.41979
     2      157      LIMONENE     10/27/84     400.0      13.5     0.65340     0.02786     0.81229
     2      157      LIMONENE     10/27/84     420.0      33.5     0.41478     0.02718     0.52679
     2      157      LIMONENE     10/28/84     440.0      53.5     0.32822     0.02008     0.36636
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                        CHEVRON LANDTREATMENT (EL SEGUNDO)

                        PREDICTIVE MODEL - LANDTREATMENT

                   FLUX RATES IN UG/M**2-SEC     (CHEVRON.MODEL)

------------------------------- SITE=1    CLASS=2    COMPOUND=LIMONENE ----------------------------------------

      CLASS     PC      COMPOUND        SDATE          T          TO          Q          LOWER95     UPPER95

        2       157     LIMONENE      10/29/84      455.0        0.0
        2       157     LIMONENE      10/29/84      455.0       68.5     0.29007     0.02031     0.36152
        2       157     LIMONENE      10/29/84      460.0        5.0     0.99853     0.06769     1.24285
        2       157     LIMONENE      10/30/84      480.0        0.0
        2       157     LIMONENE      10/30/84      480.0       25.0     0.44655     0.03070     0.50366
        2       157     LIMONENE      10/31/84      500.0       20.0     0.47687     0.02894     0.58079
        2       157     LIMONENE      10/31/84      504.5        0.0
        2       157     LIMONENE      10/31/84      504.5       24.5     0.43085     0.02390     0.53594
        2       157     LIMONENE      11/01/84      520.0       15.5     0.51648     0.02693     0.57195
        2       157     LIMONENE      11/01/84      528.0        0.0
        2       157     LIMONENE      11/01/84      528.0       23.5     0.41945     0.02243     0.48714
        2       157     LIMONENE      11/01/84      540.0       12.0     0.55691     0.05119     0.63020
        2       157     LIMONENE      11/02/84      552.0        0.0
        2       157     LIMONENE      11/02/84      552.0       24.0     0.39521     0.01928     0.46535
        2       157     LIMONENE      11/02/84      560.0        8.0     0.64971     0.04414     0.76786
        2       157     LIMONENE      11/03/84      580.0       28.0     0.34729     0.02091     0.43091
        2       157     LIMONENE      11/04/84      600.0       48.0     0.26524     0.02074     0.31976
        2       157     LIMONENE      11/05/84      620.0       68.0     0.22285     0.01246     0.27984
        2       157     LIMONENE      11/05/84      628.0        0.0
        2       157     LIMONENE      11/05/84      628.0       76.0     0.21079     0.01033     0.25427
        2       157     LIMONENE      11/06/84      640.0       12.0     0.47867     0.02853     0.60620
        2       157     LIMONENE      11/06/84      660.0       32.0     0.29313     0.01934     0.34300
        2       157     LIMONENE      11/07/84      680.0       52.0     0.22995     0.01060     0.25781
        2       157     LIMONENE      11/08/84      700.0       72.0     0.19542     0.01328     0.24373
        2       157     LIMONENE      11/09/84      720.0       92.0     0.17288     0.00787     0.21418
        2       157     LIMONENE      11/09/84      722.5        0.0
        2       157     LIMONENE      11/09/84      722.5       94.5     0.17057     0.01001     0.20659
        2       157     LIMONENE      11/10/84      740.0       17.5     0.34791     0.02245     0.41934
        2       157     LIMONENE      11/11/84      760.0       37.5     0.23767     0.01593     0.30962
        2       157     LIMONENE      11/11/84      780.0       57.5     0.19193     0.00740     0.22577
        2       157     LIMONENE      11/12/84      793.0        0.0
        2       157     LIMONENE      11/12/84      793.0       70.5     0.17334     0.00865     0.19414
        2       157     LIMONENE      11/12/84      800.0        7.0     0.48397     0.02842     0.58685
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                              CHEVRON LANDTREATMENT (EL SEGUNDO)

                               PREDICTIVE MODEL - LANDTREATMENT

                         FLUX RATES IN UG/M**2-SEC     (CHEVRON.MODEL)

--------------------------------- SITE=1   CLASS=3   COMPOUND=TOLUENE ----------------------------------

     CLASS     PC      COMPOUND       SDATE          T          TO           Q         LOWER95      UPPER95

       3       108     TOLUENE      10/10/84        2.0        2.0      27.17212     0.81415     30.36837
       3       108     TOLUENE      10/11/84       20.0       20.0       8.59258     0.22868     11.39714
       3       108     TOLUENE      10/12/84       40.0       40.0       6.07587     0.25147      7.35639
       3       108     TOLUENE      10/12/84       50.5        0.0
       3       108     TOLUENE      10/12/84       50.5       50.5       5.40745     0.14337      7.05545
       3       108     TOLUENE      10/12/84       60.0        9.5      10.47926     0.25512     13.47680
       3       108     TOLUENE      10/13/84       80.0       29.5       5.94677     0.15896      7.82848
       3       108     TOLUENE      10/14/84      100.0       49.5       4.59082     0.13836      5.95051
       3       108     TOLUENE      10/15/84      120.0       69.5       3.87436     0.16968      5.07783
       3       108     TOLUENE      10/15/84      120.5        0.0
       3       108     TOLUENE      10/15/84      120.5       70.0       3.86050     0.11384      4.77027
       3       108     TOLUENE      10/16/84      140.0       19.5       5.61292     0.18844      7.01004
       3       108     TOLUENE      10/16/84      147.5        0.0
       3       108     TOLUENE      10/16/84      147.5       27.0       4.77006     0.17805      5.34858
       3       108     TOLUENE      10/17/84      160.0       12.5       5.72668     0.20970      6.75259
       3       108     TOLUENE      10/17/84      180.0       32.5       3.55154     0.09483      4.36789
       3       108     TOLUENE      10/18/84      191.0        0.0
       3       108     TOLUENE      10/18/84      191.0       43.5       3.06982     0.14333      3.73817
       3       108     TOLUENE      10/18/84      200.0        9.0       4.69036     0.20438      5.99128
       3       108     TOLUENE      10/19/84      220.0        0.0
       3       108     TOLUENE      10/19/84      220.0       29.0       2.61293     0.14463      3.30567
       3       108     TOLUENE      10/20/84      240.0       20.0       1.97143     0.08194      2.33412
       3       108     TOLUENE      10/21/84      260.0       40.0       1.39401     0.03978      1.60685
       3       108     TOLUENE      10/22/84      280.0       60.0       1.13821     0.03956      1.37635
       3       108     TOLUENE      10/22/84      300.0       80.0       0.98572     0.03873      1.25149
       3       108     TOLUENE      10/23/84      320.0      100.0       0.88165     0.02792      1.03650
       3       108     TOLUENE      10/24/84      338.5        0.0
       3       108     TOLUENE      10/24/84      338.5      118.5       0.80991     0.02832      1.02155
       3       108     TOLUENE      10/24/84      340.0        1.5
       3       108     TOLUENE      10/25/84      360.0       21.5
       3       108     TOLUENE      10/26/84      380.0       41.5
       3       108     TOLUENE      10/26/84      386.5        0.0
       3       108     TOLUENE      10/26/84      386.5       48.0
       3       108     TOLUENE      10/27/84      400.0       13.5
       3       108     TOLUENE      10/27/84      420.0       33.5
       3       108     TOLUENE      10/28/84      440.0       53.5
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                    CHEVRON LANDTREATMENT (EL SEGUNDO)

                     PREDICTIVE MODEL - LANDTREATMENT

               FLUX RATES IN UG/M**2-SEC    (CHEVRON.MODEL)

-------------------------------- SITE=1   CLASS=3   COMPOUND=TOLUENE ------------------------------------

    CLASS    PC     COMPOUND     SDATE         T         TO      Q    LOWER95    UPPER95

      3      108    TOLUENE     10/29/84     455.0       0.0
      3      108    TOLUENE     10/29/84     455.0      68.5
      3      108    TOLUENE     10/29/84     460.0       5.0
      3      108    TOLUENE     10/30/84     480.0       0.0
      3      108    TOLUENE     10/30/84     480.0      25.0
      3      108    TOLUENE     10/31/84     500.0      20.0
      3      108    TOLUENE     10/31/84     504.5       0.0
      3      108    TOLUENE     10/31/84     504.5      24.5
      3      108    TOLUENE     11/01/84     520.0      15.5
      3      108    TOLUENE     11/01/84     528.0       0.0
      3      108    TOLUENE     11/01/84     528.0      23.5
      3      108    TOLUENE     11/01/84     540.0      12.0
      3      108    TOLUENE     11/02/84     552.0       0.0
      3      108    TOLUENE     11/02/84     552.0      24.0
      3      108    TOLUENE     11/02/84     560.0       8.0
      3      108    TOLUENE     11/03/84     580.0      28.0
      3      108    TOLUENE     11/04/84     600.0      48.0
      3      108    TOLUENE     11/05/84     620.0      68.0
      3      108    TOLUENE     11/05/84     628.0       0.0
      3      108    TOLUENE     11/05/84     628.0      76.0
      3      108    TOLUENE     11/06/84     640.0      12.0
      3      108    TOLUENE     11/06/84     660.0      32.0
      3      108    TOLUENE     11/07/84     680.0      52.0
      3      108    TOLUENE     11/08/84     700.0      72.0
      3      108    TOLUENE     11/09/84     720.0      92.0
      3      108    TOLUENE     11/09/84     722.5       0.0
      3      108    TOLUENE     11/09/84     722.5      94.5
      3      108    TOLUENE     11/10/84     740.0      17.5
      3      108    TOLUENE     11/11/84     760.0      37.5
      3      108    TOLUENE     11/11/84     780.0      57.5
      3      108    TOLUENE     11/12/84     793.0       0.0
      3      108    TOLUENE     11/12/84     793.0      70.5
      3      108    TOLUENE     11/12/84     800.0       7.0
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                         CHEVRON LANDTREATMENT (EL SEGUNDO)

                          PREDICTIVE MODEL - LANDTREATMENT

                    FLUX RATES IN UG/M**2-SEC     (CHEVRON.MODEL)

----------------------------- SITE=1    CLASS=3   COMPOUND=P-XYLENE/M-XYLENE ----------------------------

 CLASS      PC        COMPOUND            SDATE          T         TO          Q          LOWER95      UPPER95

   3       124    P-XYLENE/M-XYLENE     10/10/84        2.0        2.0      11.89431      0.44371     14.90033
   3       124    P-XYLENE/M-XYLENE     10/11/84       20.0       20.0       3.76131      0.13107      4.40160
   3       124    P-XYLENE/M-XYLENE     10/12/84       40.0       40.0       2.65965      0.09121      3.26551
   3       124    P-XYLENE/M-XYLENE     10/12/84       50.5        0.0
   3       124    P-XYLENE/M-XYLENE     10/12/84       50.5       50.5       2.36706      0.07232      3.28295
   3       124    P-XYLENE/M-XYLENE     10/12/84       60.0        9.5       5.03011      0.16921      6.75506
   3       124    P-XYLENE/M-XYLENE     10/13/84       80.0       29.5       2.85449      0.07532      3.39141
   3       124    P-XYLENE/M-XYLENE     10/14/84      100.0       49.5       2.20362      0.09024      2.80505
   3       124    P-XYLENE/M-XYLENE     10/15/84      120.0       69.5       1.85972      0.04363      2.12017
   3       124    P-XYLENE/M-XYLENE     10/15/84      120.5        0.0
   3       124    P-XYLENE/M-XYLENE     10/15/84      120.5       70.0       1.85306      0.05221      1.97349
   3       124    P-XYLENE/M-XYLENE     10/16/84      140.0       19.5       3.15548      0.09790      3.57081
   3       124    P-XYLENE/M-XYLENE     10/16/84      147.5        0.0
   3       124    P-XYLENE/M-XYLENE     10/16/84      147.5       27.0       2.68164      0.08768      3.16901
   3       124    P-XYLENE/M-XYLENE     10/17/84      160.0       12.5       3.67011      0.12072      4.81140
   3       124    P-XYLENE/M-XYLENE     10/17/84      180.0       32.5       2.27611      0.08149      2.43128
   3       124    P-XYLENE/M-XYLENE     10/18/84      191.0        0.0
   3       124    P-XYLENE/M-XYLENE     10/18/84      191.0       43.5       1.96739      0.08561      2.44092
   3       124    P-XYLENE/M-XYLENE     10/18/84      200.0        9.0       3.91417      0.14959      4.91382
   3       124    P-XYLENE/M-XYLENE     10/19/84      220.0        0.0
   3       124    P-XYLENE/M-XYLENE     10/19/84      220.0       29.0       2.18053      0.08485      2.63254
   3       124    P-XYLENE/M-XYLENE     10/20/84      240.0       20.0       2.40169      0.09455      2.67716
   3       124    P-XYLENE/M-XYLENE     10/21/84      260.0       40.0       1.69824      0.06122      2.04040
   3       124    P-XYLENE/M-XYLENE     10/22/84      280.0       60.0       1.38661      0.06200      1.74593
   3       124    P-XYLENE/M-XYLENE     10/22/84      300.0       80.0       1.20084      0.05946      1.39977
   3       124    P-XYLENE/M-XYLENE     10/23/84      320.0      100.0       1.07406      0.03868      1.32417
   3       124    P-XYLENE/M-XYLENE     10/24/84      338.5        0.0
   3       124    P-XYLENE/M-XYLENE     10/24/84      338.5      118.5       0.98667      0.03289      1.08425
   3       124    P-XYLENE/M-XYLENE     10/24/84      340.0        1.5       7.01012      0.25643      9.65665
   3       124    P-XYLENE/M-XYLENE     10/25/84      360.0       21.5       1.85162      0.06421      2.22261
   3       124    P-XYLENE/M-XYLENE     10/26/84      380.0       41.5       1.33275      0.04478      1.75879
   3       124    P-XYLENE/M-XYLENE     10/26/84      386.5        0.0
   3       124    P-XYLENE/M-XYLENE     10/26/84      386.5       48.0       1.23923      0.04284      1.41881
   3       124    P-XYLENE/M-XYLENE     10/27/84      400.0       13.5       1.97248      0.07133      2.45215
   3       124    P-XYLENE/M-XYLENE     10/27/84      420.0       33.5       1.25215      0.05749      1.59029
   3       124    P-XYLENE/M-XYLENE     10/28/84      440.0       53.5       0.99084      0.04655      1.10596
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                         CHEVRON LANDTREATMENT (EL SEGUNDO)

                         PREDICTIVE MODEL - LANDTREATMENT

                      FLUX RATES IN UG/M**2-SEC    (CHEVRON.MODEL)

-------------------------- SITE=1   CLASS=3   COMPOUND=P-XYLENE/M-XYLENE ----------------------------

 CLASS    PC       COMPOUND            SDATE        T       TO        Q        LOWER95    UPPER95

   3      124   P-XYLENE/M-XYLENE    10/29/84     455.0     0.0
   3      124   P-XYLENE/M-XYLENE    10/29/84     455.0    68.5    0.87566    0.03754    1.09137
   3      124   P-XYLENE/M-XYLENE    10/29/84     460.0     5.0    2.49630    0.10363    3.10710
   3      124   P-XYLENE/M-XYLENE    10/30/84     480.0     0.0
   3      124   P-XYLENE/M-XYLENE    10/30/84     480.0    25.0    1.11638    0.05526    1.25914
   3      124   P-XYLENE/M-XYLENE    10/31/84     500.0    20.0    1.02995    0.03863    1.25441
   3      124   P-XYLENE/M-XYLENE    10/31/84     504.5     0.0
   3      124   P-XYLENE/M-XYLENE    10/31/84     504.5    24.5    0.93057    0.03161    1.15754
   3      124   P-XYLENE/M-XYLENE    11/01/84     520.0    15.5    0.91914    0.04042    1.01787
   3      124   P-XYLENE/M-XYLENE    11/01/84     528.0     0.0
   3      124   P-XYLENE/M-XYLENE    11/01/84     528.0    23.5    0.74647    0.02444    0.86694
   3      124   P-XYLENE/M-XYLENE    11/01/84     540.0    12.0    0.75531    0.05097    0.85166
   3      124   P-XYLENE/M-XYLENE    11/02/84     552.0     0.0
   3      124   P-XYLENE/M-XYLENE    11/02/84     552.0    24.0    0.53408    0.01817    0.62887
   3      124   P-XYLENE/M-XYLENE    11/02/84     560.0     8.0    0.53385    0.02221    0.63093
   3      124   P-XYLENE/M-XYLENE    11/03/84     580.0    28.0    0.28535    0.01092    0.35406
   3      124   P-XYLENE/M-XYLENE    11/04/84     600.0    48.0    0.21794    0.01056    0.26274
   3      124   P-XYLENE/M-XYLENE    11/05/84     620.0    68.0    0.18311    0.00720    0.22994
   3      124   P-XYLENE/M-XYLENE    11/05/84     628.0     0.0
   3      124   P-XYLENE/M-XYLENE    11/05/84     628.0    76.0    0.17320    0.00520    0.20893
   3      124   P-XYLENE/M-XYLENE    11/06/84     640.0    12.0
   3      124   P-XYLENE/M-XYLENE    11/06/84     660.0    32.0
   3      124   P-XYLENE/M-XYLENE    11/07/84     680.0    52.0
   3      124   P-XYLENE/M-XYLENE    11/08/84     700.0    72.0
   3      124   P-XYLENE/M-XYLENE    11/09/84     720.0    92.0
   3      124   P-XYLENE/M-XYLENE    11/09/84     722.5     0.0
   3      124   P-XYLENE/M-XYLENE    11/09/84     722.5    94.5
   3      124   P-XYLENE/M-XYLENE    11/10/84     740.0    17.5
   3      124   P-XYLENE/M-XYLENE    11/11/84     760.0    37.5
   3      124   P-XYLENE/M-XYLENE    11/11/84     780.0    57.5
   3      124   P-XYLENE/M-XYLENE    11/12/84     793.0     0.0
   3      124   P-XYLENE/M-XYLENE    11/12/84     793.0    70.5
   3      124   P-XYLENE/M-XYLENE    11/12/84     800.0     7.0
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                         CHEVRON LANDTREATMENT (EL SEGUNDO)

                          PREDICTIVE MODEL - LANDTREATMENT

                      FLUX RATES IN UG/M**2-SEC    (CHEVRON.MODEL)

---------------------------- SITE=1   CLASS=3   COMPOUND=O-ETHYLTOLUENE ----------------------------

   CLASS     PC       COMPOUND         SDATE          T        TO         Q       LOWER95     UPPER95

     3      143    O-ETHYLTOLUENE    10/10/84       2.0       2.0    3.63232    0.15526     4.44697
     3      143    O-ETHYLTOLUENE    10/11/84      20.0      20.0    1.14864    0.03568     1.39316
     3      143    O-ETHYLTOLUENE    10/12/84      40.0      40.0    0.81221    0.04808     1.04078
     3      143    O-ETHYLTOLUENE    10/12/84      50.5       0.0
     3      143    O-ETHYLTOLUENE    10/12/84      50.5      50.5    0.72286    0.03535     0.88622
     3      143    O-ETHYLTOLUENE    10/12/84      60.0       9.5    1.60016    0.05900     2.05391
     3      143    O-ETHYLTOLUENE    10/13/84      80.0      29.5    0.90806    0.03379     1.07707
     3      143    O-ETHYLTOLUENE    10/14/84     100.0      49.5    0.70101    0.03470     0.79901
     3      143    O-ETHYLTOLUENE    10/15/84     120.0      69.5    0.59161    0.02657     0.74162
     3      143    O-ETHYLTOLUENE    10/15/84     120.5       0.0
     3      143    O-ETHYLTOLUENE    10/15/84     120.5      70.0    0.58949    0.02615     0.78202
     3      143    O-ETHYLTOLUENE    10/16/84     140.0      19.5    1.06201    0.03741     1.41587
     3      143    O-ETHYLTOLUENE    10/16/84     147.5       0.0
     3      143    O-ETHYLTOLUENE    10/16/84     147.5      27.0    0.90254    0.03179     1.22354
     3      143    O-ETHYLTOLUENE    10/17/84     160.0      12.5    1.28426    0.05172     1.57791
     3      143    O-ETHYLTOLUENE    10/17/84     180.0      32.5    0.79647    0.03255     0.90358
     3      143    O-ETHYLTOLUENE    10/18/84     191.0       0.0
     3      143    O-ETHYLTOLUENE    10/18/84     191.0      43.5    0.68844    0.02484     0.86296
     3      143    O-ETHYLTOLUENE    10/18/84     200.0       9.0    1.45008    0.05793     1.71982
     3      143    O-ETHYLTOLUENE    10/19/84     220.0       0.0
     3      143    O-ETHYLTOLUENE    10/19/84     220.0      29.0    0.80782    0.03306     1.09428
     3      143    O-ETHYLTOLUENE    10/20/84     240.0      20.0    0.93811    0.05274     1.14365
     3      143    O-ETHYLTOLUENE    10/21/84     260.0      40.0    0.66335    0.02426     0.73303
     3      143    O-ETHYLTOLUENE    10/22/84     280.0      60.0    0.54162    0.02635     0.65272
     3      143    O-ETHYLTOLUENE    10/22/84     300.0      80.0    0.46906    0.01717     0.58423
     3      143    O-ETHYLTOLUENE    10/23/84     320.0     100.0    0.41954    0.02328     0.55651
     3      143    O-ETHYLTOLUENE    10/24/84     338.5       0.0
     3      143    O-ETHYLTOLUENE    10/24/84     338.5     118.5    0.38540    0.02021     0.49010
     3      143    O-ETHYLTOLUENE    10/24/84     340.0       1.5    3.16446    0.14841     3.68993
     3      143    O-ETHYLTOLUENE    10/25/84     360.0      21.5    0.83585    0.03734     0.99051
     3      143    O-ETHYLTOLUENE    10/26/84     380.0      41.5    0.60162    0.03144     0.69546
     3      143    O-ETHYLTOLUENE    10/26/84     386.5       0.0
     3      143    O-ETHYLTOLUENE    10/26/84     386.5      48.0    0.55940    0.02481     0.72895
     3      143    O-ETHYLTOLUENE    10/27/84     400.0      13.5    1.00013    0.04274     1.29353
     3      143    O-ETHYLTOLUENE    10/27/84     420.0      33.5    0.63490    0.02730     0.70754
     3      143    O-ETHYLTOLUENE    10/28/84     440.0      53.5    0.50240    0.02546     0.57689
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                    CHEVRON LANDTREATMENT (EL SEGUNDO)

                   PREDICTIVE MODEL - LANDTREATMENT

               FLUX RATES IN UG/M**2-SEC    (CHEVRON.MODEL)

---------------------------- SITE=1   CLASS=3   COMPOUND=O-ETHYLTOLUENE ---------------------------------

 CLASS    PC      COMPOUND        SDATE        T        TO         Q         LOWER95     UPPER95

   3     143   O-ETHYLTOLUENE   10/29/84    455.0      0.0
   3     143   O-ETHYLTOLUENE   10/29/84    455.0     68.5    0.44400     0.02826     0.57395
   3     143   O-ETHYLTOLUENE   10/29/84    460.0      5.0    1.53527     0.07804     1.82191
   3     143   O-ETHYLTOLUENE   10/30/84    480.0      0.0
   3     143   O-ETHYLTOLUENE   10/30/84    480.0     25.0    0.68659     0.02367     0.78170
   3     143   O-ETHYLTOLUENE   10/31/84    500.0     20.0    0.73537     0.03198     0.89377
   3     143   O-ETHYLTOLUENE   10/31/84    504.5      0.0
   3     143   O-ETHYLTOLUENE   10/31/84    504.5     24.5    0.66441     0.03473     0.84276
   3     143   O-ETHYLTOLUENE   11/01/84    520.0     15.5    0.79902     0.04498     0.97954
   3     143   O-ETHYLTOLUENE   11/01/84    528.0      0.0
   3     143   O-ETHYLTOLUENE   11/01/84    528.0     23.5    0.64892     0.02496     0.73098
   3     143   O-ETHYLTOLUENE   11/01/84    540.0     12.0    0.86767     0.04451     1.04666
   3     143   O-ETHYLTOLUENE   11/02/84    552.0      0.0
   3     143   O-ETHYLTOLUENE   11/02/84    552.0     24.0    0.61353     0.03286     0.68723
   3     143   O-ETHYLTOLUENE   11/02/84    560.0      8.0    1.01256     0.05153     1.15875
   3     143   O-ETHYLTOLUENE   11/03/84    580.0     28.0    0.54123     0.02706     0.61026
   3     143   O-ETHYLTOLUENE   11/04/84    600.0     48.0    0.41337     0.01994     0.54292
   3     143   O-ETHYLTOLUENE   11/05/84    620.0     68.0    0.34730     0.01704     0.46560
   3     143   O-ETHYLTOLUENE   11/05/84    628.0      0.0
   3     143   O-ETHYLTOLUENE   11/05/84    628.0     76.0    0.32852     0.01344     0.39580
   3     143   O-ETHYLTOLUENE   11/06/84    640.0     12.0    0.75230     0.03677     0.88735
   3     143   O-ETHYLTOLUENE   11/06/84    660.0     32.0    0.46069     0.01647     0.60094
   3     143   O-ETHYLTOLUENE   11/07/84    680.0     52.0    0.36139     0.01748     0.41486
   3     143   O-ETHYLTOLUENE   11/08/84    700.0     72.0    0.30713     0.01349     0.37309
   3     143   O-ETHYLTOLUENE   11/09/84    720.0     92.0    0.27170     0.01111     0.35831
   3     143   O-ETHYLTOLUENE   11/09/84    722.5      0.0
   3     143   O-ETHYLTOLUENE   11/09/84    722.5     94.5    0.26808     0.01318     0.33166
   3     143   O-ETHYLTOLUENE   11/10/84    740.0     17.5    0.55344     0.02586     0.65189
   3     143   O-ETHYLTOLUENE   11/11/84    760.0     37.5    0.37807     0.01911     0.42699
   3     143   O-ETHYLTOLUENE   11/11/84    780.0     57.5    0.30532     0.01818     0.37195
   3     143   O-ETHYLTOLUENE   11/12/84    793.0      0.0
   3     143   O-ETHYLTOLUENE   11/12/84    793.0     70.5    0.27574     0.00960     0.36227
   3     143   O-ETHYLTOLUENE   11/12/84    800.0      7.0    0.78028     0.02780     0.89622
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                         CHEVRON LANDTREATMENT (EL SESUNDO)

                          PREDICTIVE MODEL - LANDTREATMENT

                     FLUX RATES IN UG/M**2-SEC    (CHEVRON.MOD)

------------------------------ SITE=1   CLASS=20   COMPOUND=PARAFFINS ----------------------------------

        CLASS     PC      COMPOUND         T        TO          Q          LOWER95      UPPER95

         20      201     PARAFFINS       2.0       2.0     387.76445     2.85182     474.73164
         20      201     PARAFFINS      20.0      20.0     122.62189     0.65528     148.72562
         20      201     PARAFFINS      40.0      40.0      86.70677     1.03587     111.10721
         20      201     PARAFFINS      50.5       0.0
         20      201     PARAFFINS      50.5      50.5      77.16801     0.51779      96.63731
         20      201     PARAFFINS      60.0       9.5     154.38812     0.97946     198.16664
         20      201     PARAFFINS      80.0      29.5      87.61222     0.56246     103.91912
         20      201     PARAFFINS     100.0      49.5      67.63525     0.62304      77.09030
         20      201     PARAFFINS     120.0      69.5      57.07991     0.44115      71.55394
         20      201     PARAFFINS     120.5       0.0
         20      201     PARAFFINS     120.5      70.0      56.87569     0.29618      63.48102
         20      201     PARAFFINS     140.0      19.5      87.86599     0.70565     117.14221
         20      201     PARAFFINS     147.5       0.0
         20      201     PARAFFINS     147.5      27.0      74.67173     0.77655      84.69208
         20      201     PARAFFINS     160.0      12.5      94.70682     0.87964     116.36177
         20      201     PARAFFINS     180.0      32.5      58.73467     0.55602      66.63356
         20      201     PARAFFINS     191.0       0.0
         20      201     PARAFFINS     191.0      43.5      50.76818     0.39234      61.00617
         20      201     PARAFFINS     200.0       9.0      88.20488     0.68087     104.61242
         20      201     PARAFFINS     220.0       0.0
         20      201     PARAFFINS     220.0      29.0      49.13771     0.59824      61.96947
         20      201     PARAFFINS     240.0      20.0      46.29147     0.54744      56.43387
         20      201     PARAFFINS     260.0      40.0      32.73301     0.42238      36.17143
         20      201     PARAFFINS     280.0      60.0      26.72639     0.24398      32.20894
         20      201     PARAFFINS     300.0      80.0      23.14573     0.17304      28.82924
         20      201     PARAFFINS     320.0     100.0      20.70217     0.21118      27.46098
         20      201     PARAFFINS     338.5       0.0
         20      201     PARAFFINS     338.5     118.5      19.01765     0.10493      23.69308
         20      201     PARAFFINS     340.0       1.5
         20      201     PARAFFINS     360.0      21.5
         20      201     PARAFFINS     380.0      41.5
         20      201     PARAFFINS     386.5       0.0
         20      201     PARAFFINS     386.5      48.0
         20      201     PARAFFINS     400.0      13.5
         20      201     PARAFFINS     420.0      33.5
         20      201     PARAFFINS     440.0      53.5
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                    CHEVRON LANDTREATMENT (EL SEGUNDO)

                    PREDICTIVE MODEL - LANDTREATMENT

              FLUX RATES IN UG/M**2-SEC     (CHEVRON.MOD)

------------------------------ SITE=1   CLASS=20   COMPOUND=PARAFFINS ------------------------------

   CLASS    PC     COMPOUND       T        TO      Q    LOWER95    UPPER95

    20      201    PARAFFINS    455.0      0.0
    20      201    PARAFFINS    455.0     68.5
    20      201    PARAFFINS    460.0      5.0
    20      201    PARAFFINS    480.0      0.0
    20      201    PARAFFINS    480.0     25.0
    20      201    PARAFFINS    500.0     20.0
    20      201    PARAFFINS    504.5      0.0
    20      201    PARAFFINS    504.5     24.5
    20      201    PARAFFINS    520.0     15.5
    20      201    PARAFFINS    528.0      0.0
    20      201    PARAFFINS    528.0     23.5
    20      201    PARAFFINS    540.0     12.0
    20      201    PARAFFINS    552.0      0.0
    20      201    PARAFFINS    552.0     24.0
    20      201    PARAFFINS    560.0      8.0
    20      201    PARAFFINS    580.0     28.0
    20      201    PARAFFINS    600.0     48.0
    20      201    PARAFFINS    620.0     68.0
    20      201    PARAFFINS    628.0      0.0
    20      201    PARAFFINS    628.0     76.0
    20      201    PARAFFINS    640.0     12.0
    20      201    PARAFFINS    660.0     32.0
    20      201    PARAFFINS    680.0     52.0
    20      201    PARAFFINS    700.0     72.0
    20      201    PARAFFINS    720.0     92.0
    20      201    PARAFFINS    722.5      0.0
    20      201    PARAFFINS    722.5     94.5
    20      201    PARAFFINS    740.0     17.5
    20      201    PARAFFINS    760.0     37.5
    20      201    PARAFFINS    780.0     57.5
    20      201    PARAFFINS    793.0      0.0
    20      201    PARAFFINS    793.0     70.5
    20      201    PARAFFINS    800.0      7.0
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                         CHEVRON LANDTREATMENT (EL SEGUNDO)

                          PREDICTIVE MODEL - LANDTREATMENT

                    FLUX RATES IN UG/M**2-SEC     (CHEVRON.MODEL)

------------------------------ SITE=1   CLASS=20   COMPOUND=OLEFINS ------------------------------------

   CLASS    PC     COMPOUND     SDATE         T        TO        Q          LOWER95     UPPER95

    20     202     OLEFINS     10/10/84      2.0       2.0    66.34184     0.86977    81.22088
    20     202     OLEFINS     10/11/84     20.0      20.0    20.97913     0.19985    25.44517
    20     202     OLEFINS     10/12/84     40.0      40.0    14.83449     0.31593    19.00911
    20     202     OLEFINS     10/12/84     50.5       0.0
    20     202     OLEFINS     10/12/84     50.5      50.5    13.20252     0.19805    16.18626
    20     202     OLEFINS     10/12/84     60.0       9.5    28.32207     0.32030    36.35311
    20     202     OLEFINS     10/13/84     80.0      29.5    16.07221     0.18344    19.06367
    20     202     OLEFINS     10/14/84    100.0      49.5    12.40750     0.19002    14.14200
    20     202     OLEFINS     10/15/84    120.0      69.5    10.47115     0.14427    13.12637
    20     202     OLEFINS     10/15/84    120.5       0.0
    20     202     OLEFINS     10/15/84    120.5      70.0    10.43368     0.14198    13.84141
    20     202     OLEFINS     10/16/84    140.0      19.5    18.01046     0.23220    24.01140
    20     202     OLEFINS     10/16/84    147.5       0.0
    20     202     OLEFINS     10/16/84    147.5      27.0    15.30595     0.17161    20.74984
    20     202     OLEFINS     10/17/84    160.0      12.5    21.15204     0.28853    25.98850
    20     202     OLEFINS     10/17/84    180.0      32.5    13.11794     0.18232    14.88209
    20     202     OLEFINS     10/18/84    191.0       0.0
    20     202     OLEFINS     10/18/84    191.0      43.5    11.33868     0.16493    14.21302
    20     202     OLEFINS     10/18/84    200.0       9.0    22.89607     0.29522    27.15511
    20     202     OLEFINS     10/19/84    220.0       0.0
    20     202     OLEFINS     10/19/84    220.0      29.0    12.75508     0.18518    17.27807
    20     202     OLEFINS     10/20/84    240.0      20.0    14.25170     0.24595    17.37423
    20     202     OLEFINS     10/21/84    260.0      40.0    10.07747     0.13591    11.13605
    20     202     OLEFINS     10/22/84    280.0      60.0     8.22822     0.13390     9.91613
    20     202     OLEFINS     10/22/84    300.0      80.0     7.12585     0.08001     8.87562
    20     202     OLEFINS     10/23/84    320.0     100.0     6.37355     0.11549     8.45438
    20     202     OLEFINS     10/24/84    338.5       0.0
    20     202     OLEFINS     10/24/84    338.5     118.5     5.85494     0.10612     7.44560
    20     202     OLEFINS     10/24/84    340.0       1.5    43.45145     0.64123    50.66667
    20     202     OLEFINS     10/25/84    360.0      21.5    11.47706     0.17135    13.60073
    20     202     OLEFINS     10/26/84    380.0      41.5     8.26087     0.15397     9.54947
    20     202     OLEFINS     10/26/84    386.5       0.0
    20     202     OLEFINS     10/26/84    386.5      48.0     7.68120     0.13779    10.00933
    20     202     OLEFINS     10/27/84    400.0      13.5    12.70262     0.21874    16.42904
    20     202     OLEFINS     10/27/84    420.0      33.5     8.06377     0.10635     8.98647
    20     202     OLEFINS     10/28/84    440.0      53.5     6.38092     0.10486     7.32706
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                     CHEVRON LANDTREATMENT (EL SEGUNDO)

                      PREDICTIVE MODEL - LANDTREATMENT

                 FLUX RATES IN UG/M**2-SEC    (CHEVRON.MODEL)

------------------------------- SITE=1   CLASS=20   COMPOUND=OLEFINS ------------------------------------

      CLASS     PC      COMPOUND      SDATE         T          TO             Q      LOWER95      UPPER95

       20       202     OLEFINS     10/29/84      455.0        0.0
       20       202     OLEFINS     10/29/84      455.0       68.5       5.63917      0.11447      7.28972
       20       202     OLEFINS     10/29/84      460.0        5.0      17.28241      0.31582     20.50906
       20       202     OLEFINS     10/30/84      480.0        0.0
       20       202     OLEFINS     10/30/84      480.0       25.0       7.72893      0.08171      8.79956
       20       202     OLEFINS     10/31/84      500.0       20.0       7.58554      0.10181      9.21950
       20       202     OLEFINS     10/31/84      504.5        0.0
       20       202     OLEFINS     10/31/84      504.5       24.5       6.85360      0.11251      8.69333
       20       202     OLEFINS     11/01/84      520.0       15.5       7.41875      0.13834      9.09481
       20       202     OLEFINS     11/01/84      528.0        0.0
       20       202     OLEFINS     11/01/84      528.0       23.5       6.02508      0.09853      6.78703
       20       202     OLEFINS     11/01/84      540.0       12.0       7.08308      0.11200      8.54432
       20       202     OLEFINS     11/02/84      552.0        0.0
       20       202     OLEFINS     11/02/84      552.0       24.0       5.00849      0.08227      5.61015
       20       202     OLEFINS     11/02/84      560.0        8.0       6.97235      0.14484      7.97904
       20       202     OLEFINS     11/03/84      580.0       28.0       3.72688      0.06205      4.20219
       20       202     OLEFINS     11/04/84      600.0       48.0       2.84645      0.05097      3.73850
       20       202     OLEFINS     11/05/84      620.0       68.0       2.39150      0.03763      3.20610
       20       202     OLEFINS     11/05/84      628.0        0.0
       20       202     OLEFINS     11/05/84      628.0       76.0       2.26213      0.04057      2.72541
       20       202     OLEFINS     11/06/84      640.0       12.0       2.64701      0.03969      3.12219
       20       202     OLEFINS     11/06/84      660.0       32.0       1.62096      0.02190      2.11444
       20       202     OLEFINS     11/07/84      680.0       52.0       1.27158      0.01958      1.45970
       20       202     OLEFINS     11/08/84      700.0       72.0       1.08064      0.01616      1.31272
       20       202     OLEFINS     11/09/84      720.0       92.0       0.95599      0.01284      1.26073
       20       202     OLEFINS     11/09/84      722.5        0.0
       20       202     OLEFINS     11/09/84      722.5       94.5       0.94326      0.01695      1.16697
       20       202     OLEFINS     11/10/84      740.0       17.5
       20       202     OLEFINS     11/11/84      760.0       37.5
       20       202     OLEFINS     11/11/84      780.0       57.5
       20       202     OLEFINS     11/12/84      793.0        0.0
       20       202     OLEFINS     11/12/84      793.0       70.5
       20       202     OLEFINS     11/12/84      800.0        7.0
```

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                    CHEVRON LANDTREATMENT (EL SEGUNDO)

                    PREDICTIVE MODEL - LANDTREATMENT

               FLUX RATES IN UG/M**2-SEC    (CHEVRON.MODEL)

---------------------------- SITE=1   CLASS=20   COMPOUND=TOTAL AROMATICS -------------------------------

  CLASS    PC       COMPOUND          SDATE          T        TO          Q         LOWER95      UPPER95

   20      203   TOTAL AROMATICS    10/10/84       2.0       2.0    191.16737    1.73295    213.65428
   20      203   TOTAL AROMATICS    10/11/84      20.0      20.0     60.45243    0.48676     80.18370
   20      203   TOTAL AROMATICS    10/12/84      40.0      40.0     42.74632    0.53526     51.75527
   20      203   TOTAL AROMATICS    10/12/84      50.5       0.0
   20      203   TOTAL AROMATICS    10/12/84      50.5      50.5     38.04373    0.30517     49.63805
   20      203   TOTAL AROMATICS    10/12/84      60.0       9.5     78.99033    0.58181    101.58512
   20      203   TOTAL AROMATICS    10/13/84      80.0      29.5     44.82546    0.36252     59.00935
   20      203   TOTAL AROMATICS    10/14/84     100.0      49.5     34.60455    0.29450     44.85364
   20      203   TOTAL AROMATICS    10/15/84     120.0      69.5     29.20407    0.38697     38.27558
   20      203   TOTAL AROMATICS    10/15/84     120.5       0.0
   20      203   TOTAL AROMATICS    10/15/84     120.5      70.0     29.09958    0.25962     35.95721
   20      203   TOTAL AROMATICS    10/16/84     140.0      19.5     47.83928    0.48509     59.74700
   20      203   TOTAL AROMATICS    10/16/84     147.5       0.0
   20      203   TOTAL AROMATICS    10/16/84     147.5      27.0     40.65557    0.44906     45.58631
   20      203   TOTAL AROMATICS    10/17/84     160.0      12.5     54.21022    0.61175     63.92174
   20      203   TOTAL AROMATICS    10/17/84     180.0      32.5     33.61975    0.27160     41.34751
   20      203   TOTAL AROMATICS    10/18/84     191.0       0.0
   20      203   TOTAL AROMATICS    10/18/84     191.0      43.5     29.05973    0.36471     35.38646
   20      203   TOTAL AROMATICS    10/18/84     200.0       9.0     55.42215    0.47210     70.79408
   20      203   TOTAL AROMATICS    10/19/84     220.0       0.0
   20      203   TOTAL AROMATICS    10/19/84     220.0      29.0     30.87490    0.31703     39.06035
   20      203   TOTAL AROMATICS    10/20/84     240.0      20.0     32.56235    0.40945     38.55288
   20      203   TOTAL AROMATICS    10/21/84     260.0      40.0     23.02506    0.19879     26.54055
   20      203   TOTAL AROMATICS    10/22/84     280.0      60.0     18.79988    0.19766     22.73337
   20      203   TOTAL AROMATICS    10/22/84     300.0      80.0     16.28118    0.19354     20.67109
   20      203   TOTAL AROMATICS    10/23/84     320.0     100.0     14.56233    0.13681     17.12007
   20      203   TOTAL AROMATICS    10/24/84     338.5       0.0
   20      203   TOTAL AROMATICS    10/24/84     338.5     118.5     13.37740    0.14152     16.87306
   20      203   TOTAL AROMATICS    10/24/84     340.0       1.5     80.85872    1.11871    110.51432
   20      203   TOTAL AROMATICS    10/25/84     360.0      21.5     21.35764    0.27885     25.74745
   20      203   TOTAL AROMATICS    10/26/84     380.0      41.5     15.37264    0.17536     17.14615
   20      203   TOTAL AROMATICS    10/26/84     386.5       0.0
   20      203   TOTAL AROMATICS    10/26/84     386.5      48.0     14.29394    0.18143     17.65166
   20      203   TOTAL AROMATICS    10/27/84     400.0      13.5     19.00012    0.30748     24.03172
   20      203   TOTAL AROMATICS    10/27/84     420.0      33.5     12.06148    0.13528     14.45110
   20      203   TOTAL AROMATICS    10/28/84     440.0      53.5      9.54435    0.12010     12.96319
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                              CHEVRON LANDTREATMENT (EL SEGUNDO)

                              PREDICTIVE MODEL - LANDTREATMENT

                         FLUX RATES IN UG/M**2-SEC     (CHEVRON.MODEL)

---------------------------- SITE=1   CLASS=20   COMPOUND=TOTAL AROMATICS -----------------------------

  CLASS     PC       COMPOUND           SDATE         T         TO            Q      LOWER95      UPPER95

   20      203    TOTAL AROMATICS    10/29/84     455.0      0.0
   20      203    TOTAL AROMATICS    10/29/84     455.0     68.5      8.43486      0.09725      9.68665
   20      203    TOTAL AROMATICS    10/29/84     460.0      5.0     11.99025      0.16470     14.68980
   20      203    TOTAL AROMATICS    10/30/84     480.0      0.0
   20      203    TOTAL AROMATICS    10/30/84     480.0     25.0      5.36220      0.06000      6.27535
   20      203    TOTAL AROMATICS    10/31/84     500.0     20.0
   20      203    TOTAL AROMATICS    10/31/84     504.5      0.0
   20      203    TOTAL AROMATICS    10/31/84     504.5     24.5
   20      203    TOTAL AROMATICS    11/01/84     520.0     15.5
   20      203    TOTAL AROMATICS    11/01/84     528.0      0.0
   20      203    TOTAL AROMATICS    11/01/84     528.0     23.5
   20      203    TOTAL AROMATICS    11/01/84     540.0     12.0
   20      203    TOTAL AROMATICS    11/02/84     552.0      0.0
   20      203    TOTAL AROMATICS    11/02/84     552.0     24.0
   20      203    TOTAL AROMATICS    11/02/84     560.0      8.0
   20      203    TOTAL AROMATICS    11/03/84     580.0     28.0
   20      203    TOTAL AROMATICS    11/04/84     600.0     48.0
   20      203    TOTAL AROMATICS    11/05/84     620.0     68.0
   20      203    TOTAL AROMATICS    11/05/84     628.0      0.0
   20      203    TOTAL AROMATICS    11/05/84     628.0     76.0
   20      203    TOTAL AROMATICS    11/06/84     640.0     12.0
   20      203    TOTAL AROMATICS    11/06/84     660.0     32.0
   20      203    TOTAL AROMATICS    11/07/84     680.0     52.0
   20      203    TOTAL AROMATICS    11/08/84     700.0     72.0
   20      203    TOTAL AROMATICS    11/09/84     720.0     92.0
   20      203    TOTAL AROMATICS    11/09/84     722.5      0.0
   20      203    TOTAL AROMATICS    11/09/84     722.5     94.5
   20      203    TOTAL AROMATICS    11/10/84     740.0     17.5
   20      203    TOTAL AROMATICS    11/11/84     760.0     37.5
   20      203    TOTAL AROMATICS    11/11/84     780.0     57.5
   20      203    TOTAL AROMATICS    11/12/84     793.0      0.0
   20      203    TOTAL AROMATICS    11/12/84     793.0     70.5
   20      203    TOTAL AROMATICS    11/12/84     800.0      7.0
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                    CHEVRON LANDTREATMENT (EL SEGUNDO)

                     PREDICTIVE MODEL - LANDTREATMENT

                 FLUX RATES IN UG/M**2-SEC     (CHEVRON.MOD)

------------------------------- SITE=1   CLASS=30   COMPOUND=TOTAL NMHC ------------------------------

      CLASS     PC       COMPOUND            T        TO          Q         LOWER95       UPPER95

       30       300     TOTAL NMHC          2.0       2.0     659.30570     4.03034     825.93012
       30       300     TOTAL NMHC         20.0      20.0     208.49077     1.16019     243.98203
       30       300     TOTAL NMHC         40.0      40.0     147.42524     0.80739     181.00847
       30       300     TOTAL NMHC         50.5       0.0
       30       300     TOTAL NMHC         50.5      50.5     131.20674     0.70485     148.62610
       30       300     TOTAL NMHC         60.0       9.5     268.41279     1.52840     360.45838
       30       300     TOTAL NMHC         80.0      29.5     152.31897     0.66673     180.97006
       30       300     TOTAL NMHC        100.0      49.5     117.58784     0.79877     149.68108
       30       300     TOTAL NMHC        120.0      69.5      99.23677     0.46360     113.13468
       30       300     TOTAL NMHC        120.5       0.0
       30       300     TOTAL NMHC        120.5      70.0      98.88171     0.55768     118.65121
       30       300     TOTAL NMHC        140.0      19.5     158.71916     0.78634     179.60974
       30       300     TOTAL NMHC        147.5       0.0
       30       300     TOTAL NMHC        147.5      27.0     134.88535     1.01213     192.39545
       30       300     TOTAL NMHC        160.0      12.5     176.54244     0.92733     231.44158
       30       300     TOTAL NMHC        180.0      32.5     109.48697     0.65023     116.95139
       30       300     TOTAL NMHC        191.0       0.0
       30       300     TOTAL NMHC        191.0      43.5      94.63668     0.47152     107.72656
       30       300     TOTAL NMHC        200.0       9.0     174.70273     1.06622     219.32082
       30       300     TOTAL NMHC        220.0       0.0
       30       300     TOTAL NMHC        220.0      29.0      97.32445     0.67599     121.40672
       30       300     TOTAL NMHC        240.0      20.0      98.97303     0.62223     110.32545
       30       300     TOTAL NMHC        260.0      40.0      69.98450     0.40291      84.08492
       30       300     TOTAL NMHC        280.0      60.0      57.14210     0.45238      71.94953
       30       300     TOTAL NMHC        300.0      80.0      49.48651     0.41049      57.68449
       30       300     TOTAL NMHC        320.0     100.0      44.26208     0.25458      54.56901
       30       300     TOTAL NMHC        338.5       0.0
       30       300     TOTAL NMHC        338.5     118.5      40.66050     0.31615      52.45216
       30       300     TOTAL NMHC        340.0       1.5     202.37028     1.18214     278.77117
       30       300     TOTAL NMHC        360.0      21.5      53.45313     0.29600      64.16302
       30       300     TOTAL NMHC        380.0      41.5      38.47409     0.28749      50.77327
       30       300     TOTAL NMHC        385.5       0.0
       30       300     TOTAL NMHC        386.5      48.0      35.77435     0.16513      41.81758
       30       300     TOTAL NMHC        400.0      13.5      31.62598     0.20114      39.31684
       30       300     TOTAL NMHC        420.0      33.5      20.07652     0.16048      25.49807
       30       300     TOTAL NMHC        440.0      53.5      15.88671     0.12328      17.73260
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                         CHEVRON LANDTREATMENT (EL SEGUNDO)

                         PREDICTIVE MODEL - LANDTREATMENT

                    FLUX RATES IN UG/M**2-SEC     (CHEVRON.MOD)

------------------------------- SITE=1   CLASS=30   COMPOUND=TOTAL NMHC ---------------------------------

          CLASS    PC      COMPOUND        T        TO          Q         LOWER95     UPPER95

           30      300    TOTAL NMHC     455.0      0.0
           30      300    TOTAL NMHC     455.0     68.5     14.03995     0.06488    16.40674
           30      300    TOTAL NMHC     460.0      5.0
           30      300    TOTAL NMHC     480.0      0.0
           30      300    TOTAL NMHC     480.0     25.0
           30      300    TOTAL NMHC     500.0     20.0
           30      300    TOTAL NMHC     504.5      0.0
           30      300    TOTAL NMHC     504.5     24.5
           30      300    TOTAL NMHC     520.0     15.5
           30      300    TOTAL NMHC     528.0      0.0
           30      300    TOTAL NMHC     528.0     23.5
           30      300    TOTAL NMHC     540.0     12.0
           30      300    TOTAL NMHC     552.0      0.0
           30      300    TOTAL NMHC     552.0     24.0
           30      300    TOTAL NMHC     560.0      8.0
           30      300    TOTAL NMHC     580.0     28.0
           30      300    TOTAL NMHC     600.0     48.0
           30      300    TOTAL NMHC     620.0     68.0
           30      300    TOTAL NMHC     628.0      0.0
           30      300    TOTAL NMHC     628.0     76.0
           30      300    TOTAL NMHC     640.0     12.0
           30      300    TOTAL NMHC     660.0     32.0
           30      300    TOTAL NMHC     680.0     52.0
           30      300    TOTAL NMHC     700.0     72.0
           30      300    TOTAL NMHC     720.0     92.0
           30      300    TOTAL NMHC     722.5      0.0
           30      300    TOTAL NMHC     722.5     94.5
           30      300    TOTAL NMHC     740.0     17.5
           30      300    TOTAL NMHC     760.0     37.5
           30      300    TOTAL NMHC     780.0     57.5
           30      300    TOTAL NMHC     793.0      0.0
           30      300    TOTAL NMHC     793.0     70.5
           30      300    TOTAL NMHC     800.0      7.0
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APPENDIX E

SAMPLING AND ANALYTICAL DUPLICATES FOR ON-SITE ANALYSES

APPENDIX E

RESULTS OF DUPLICATE SAMPLES AND ANALYSIS OF GAS SYRINGE SAMPLES

FIELD SAMPLE ID	THC ppm	THC ppm	CO2 ppm	CO2 ppm
ANALYTICAL DUPS				
C001	7.6	4.6	242	206
C002	6	4.4	107	99
C003	8	6	119	113
C004	5	7	275	273
C006	6	7.5	110	97
C007	6	10	113	108
C008	8	10	163	152
C009	5	5	80	83
C010	5	6	277	284
C037	390	487	194	188
C039	515	679	201	198
C076	206	210	127	120
C077	45	32	232	235
C079	71	72	83	84
C085	41	43	65	62
C089	9	7	99	109
C097	97	103	247	262
C099	58	62	116	110
C105	141	145	247	250
C110	19	13	101	98
C112	72	82	143	141
C128	4	3	70	71
C135	88	67	123	117
C142	133	130	179	183
C143	20	16	123	123
C150	1179	1252	381	376
C151	1179	1139	367	373
C152	452	452	185	191
C157	440	404	215	213
C168	481	517	193	196
C174	44	44	61	60
C177	116	108	113	172
C181	277	246	151	151
C185	248	265	236	238
C204	179	179	323	326
C208	248	242	174	180
C211	7	9	37	30
C213			304	357
C215	38	41	298	315
C222	21	27	207	209
C223	16	16	138	138
C240	46	52	155	155
C241	62	63	254	246
C244	19	16	116	113
C248	23	25	210	204
C254	21	23	249	254
C260	19	20	138	133
C262	34	42	171	188
C271	37	40	238	240
C275			282	282
C285			527	475

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APPENDIX E (Continued)

FIELD SAMPLE ID	THC ppm	THC ppm	CO2 ppm	CO2 ppm
C287	151	137	304	301
C288	9	5	101	84
C289	30	27	180	171
C291	22	25	152	139
C298	30	32	180	188
C300	7	5	193	166
C316	86	95	478	436
C320	69	71	276	273
C341	3	1	86	141
C345	3	1	102	52
C347	34	3	312	122
C374	2	2	36	221
C376	1	1	197	13
C382	0	1	68	12
C393	0	0	68	10
C395	0	0	96	13
C398	1	4	4	102
C406	0	0	59	30
C408	0	0	126	72
C417	0	1	66	8
C419	0	0	50	146
C423	1	0	17	36
C427	0	0	11	122
C470	26	4	414	411
C479	8	9	217	218
C481	13	15	221	213
C487	3	3	116	122
C492	44	51	199	204
C497	17	11	246	249
SAMPLING	DUPS			
C150+1	1216	1159	378	370
C192+D	111	122	307	309
C209+D	37	21	174	191
C227+8	47	40	235	232
C239+40	44	49	163	155
C256+D	24	16	163	144
C281+D	101	97	127	122
C315+D	25	21	133	56
C333+D	13	19	127	122
C363+4	38	46	320	312
C377+D	2	3	124	112
C388+D	2	1	150	51
C411+2	1	0	95	102
C430+D	8	0	130	94
C451+D	1	1	175	140
C460+D	39	103	389	384
C473+D	9	11	240	174

APPENDIX F

RESULTS OF FLUX CHAMBER BLANK RUNS

APPENDIX F

RESULTS OF FLUX CHAMBER BLANK RUNS

FIELD SAMPLE ID	FLUX CHAMBER ID	SAMPLING DATE	SAMPLING TIME	THC (ppm)	CO2 (ppm)
C030	2	10-10-84	825	0	14
C031	3	10-10-84	825	1	3
C127	1	10-11-84	1300	4	119
C128	2	10-11-84	1300	4	70
C129	1	10-12-84	850	5	197
C130	3	10-12-84	850	1	17
C131	2	10-12-84	850	2	18
C170	2	10-13-84	752	3	18
C171	1	10-13-84	752	2	26
C172	3	10-13-84	752	2	9
C211	3	10-23-84	841	8	33
C212	2	10-23-84	852	4	26
C251	3	10-24-84	814	1	42
C252	2	10-24-84	817	1	41
C312	2	10-25-84	920	5	41
C313	3	10-25-84	924	3	25
C343	3	10-26-84	1135	5	25
C344	2	10-26-84	1140	6	133
C365	2	11-8-84	900	1	89
C366	3	11-8-84	900	2	62
C403	2	11-9-84	832	0	93
C404	3	11-9-84	832	0	78
C440	3	11-10-84	853	0	140
C441	2	11-10-84	853	0	253
C482	3	11-12-84	921	3	64
C483	2	11-12-84	936	1	44

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APPENDIX G

STATISTICAL ANALYSIS RESULTS

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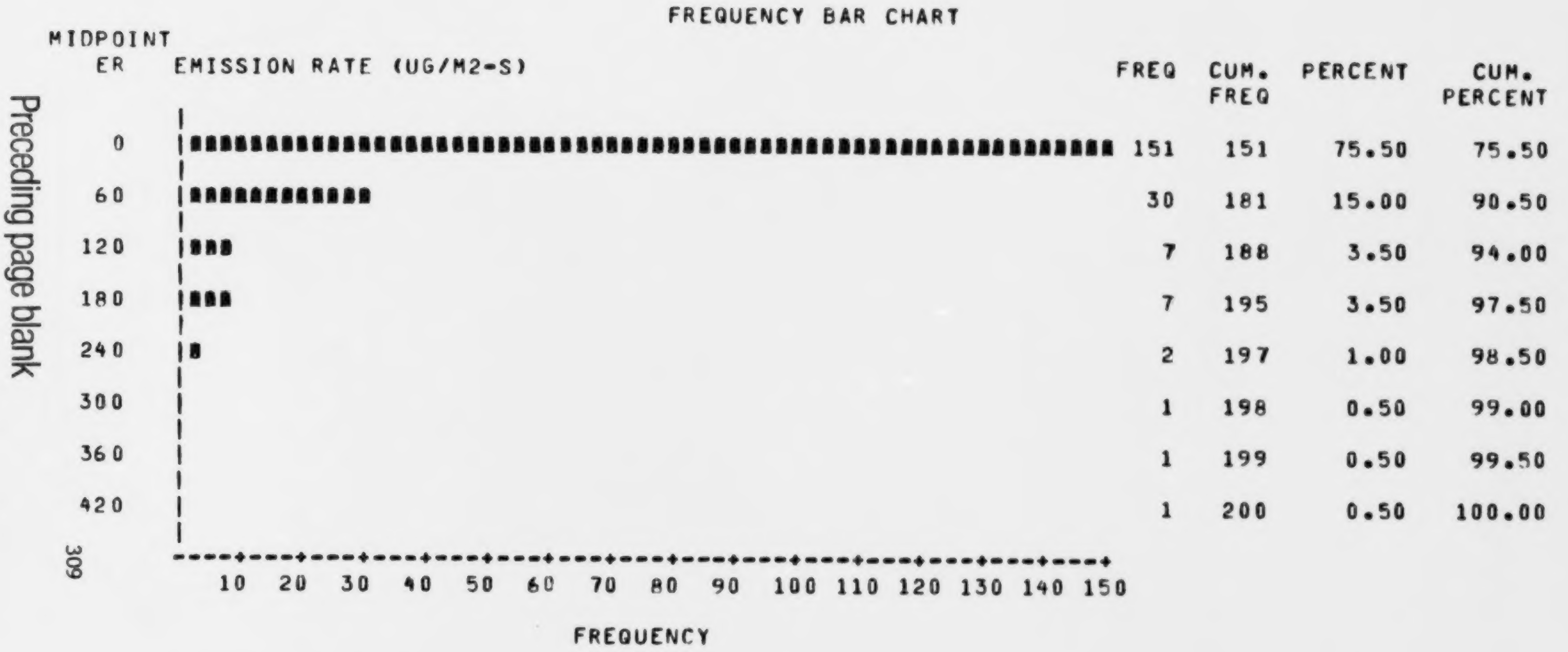

MIDPOINT ER	FREQ	CUM. FREQ	PERCENT	CUM. PERCENT
0	151	151	75.50	75.50
60	30	181	15.00	90.50
120	7	188	3.50	94.00
180	7	195	3.50	97.50
240	2	197	1.00	98.50
300	1	198	0.50	99.00
360	1	199	0.50	99.50
420	1	200	0.50	100.00

G-1. Histogram of the emission rate data.

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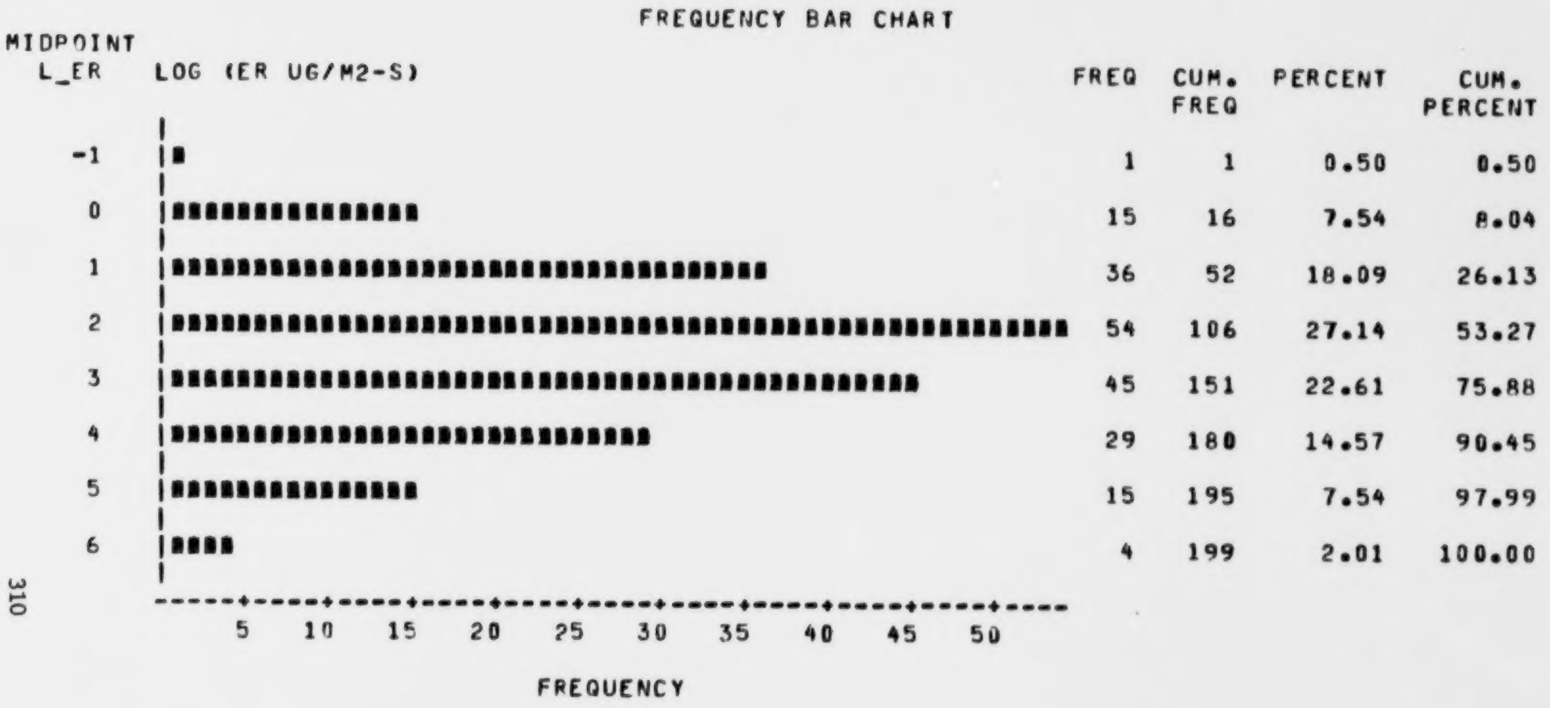

```
                          FREQUENCY BAR CHART
MIDPOINT
  L_ER   LOG (ER UG/M2-S)                                         FREQ  CUM.  PERCENT   CUM.
                                                                        FREQ           PERCENT
         |
   -1    |■                                                          1     1     0.50      0.50
         |
    0    |■■■■■■■■■■■■■■■                                           15    16     7.54      8.04
         |
    1    |■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■                      36    52    18.09     26.13
         |
    2    |■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■    54   106    27.14     53.27
         |
    3    |■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■■             45   151    22.61     75.88
         |
    4    |■■■■■■■■■■■■■■■■■■■■■■■■■■■■■                             29   180    14.57     90.45
         |
    5    |■■■■■■■■■■■■■■■                                           15   195     7.54     97.99
         |
    6    |■■■■                                                       4   199     2.01    100.00
         |
         -----+----+----+----+----+----+----+----+----+----+----
              5   10   15   20   25   30   35   40   45   50

                           FREQUENCY
```

Figure G-2. Histogram of the log of the emission rate data.

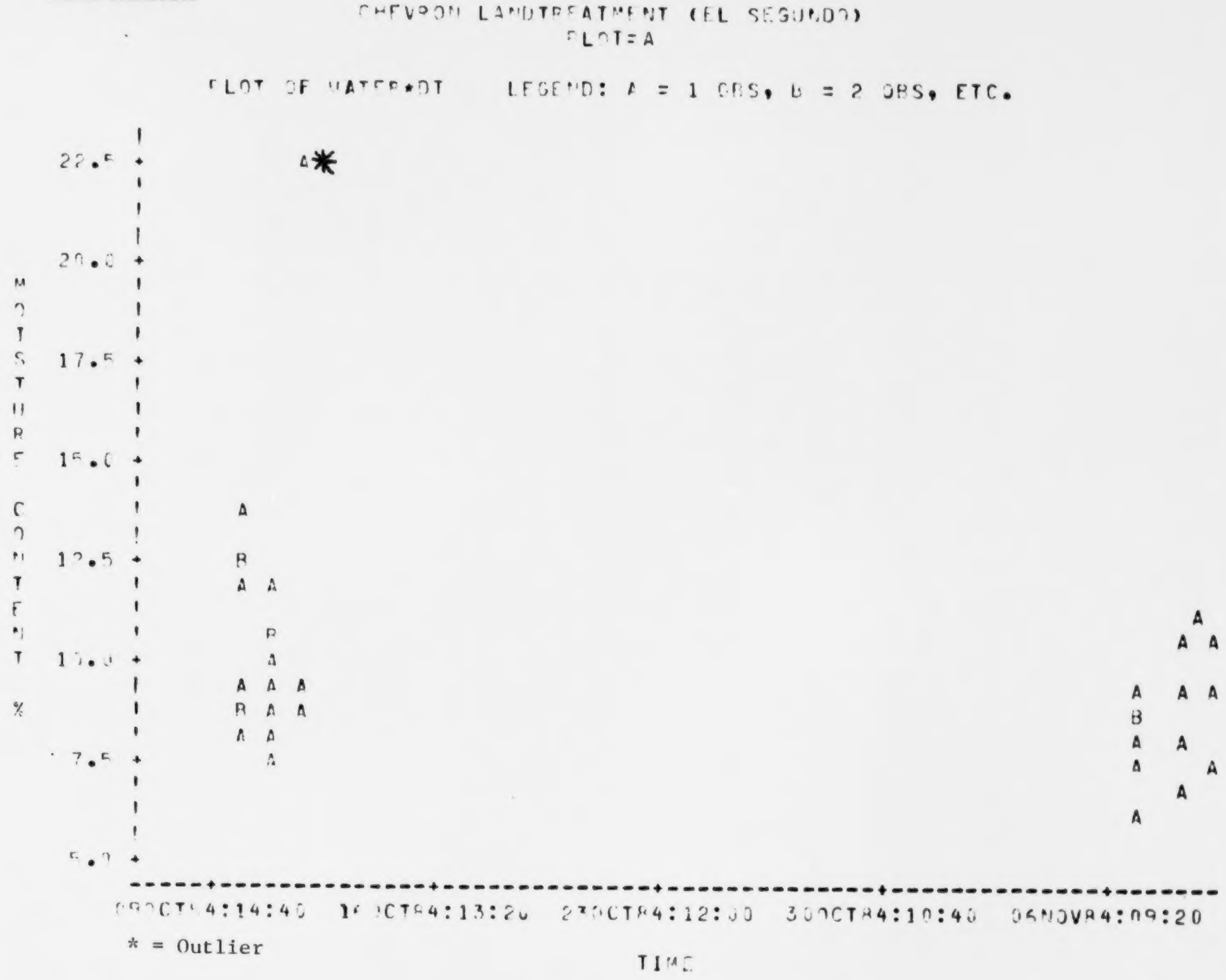

Figure G-3. Plots of soil moisture content vs. time.

CHEVRON LANDTREATMENT (EL SEGUNDO)
PLOT=B

PLOT OF WATER*DT   LEGEND: A = 1 OBS, B = 2 OBS, ETC.

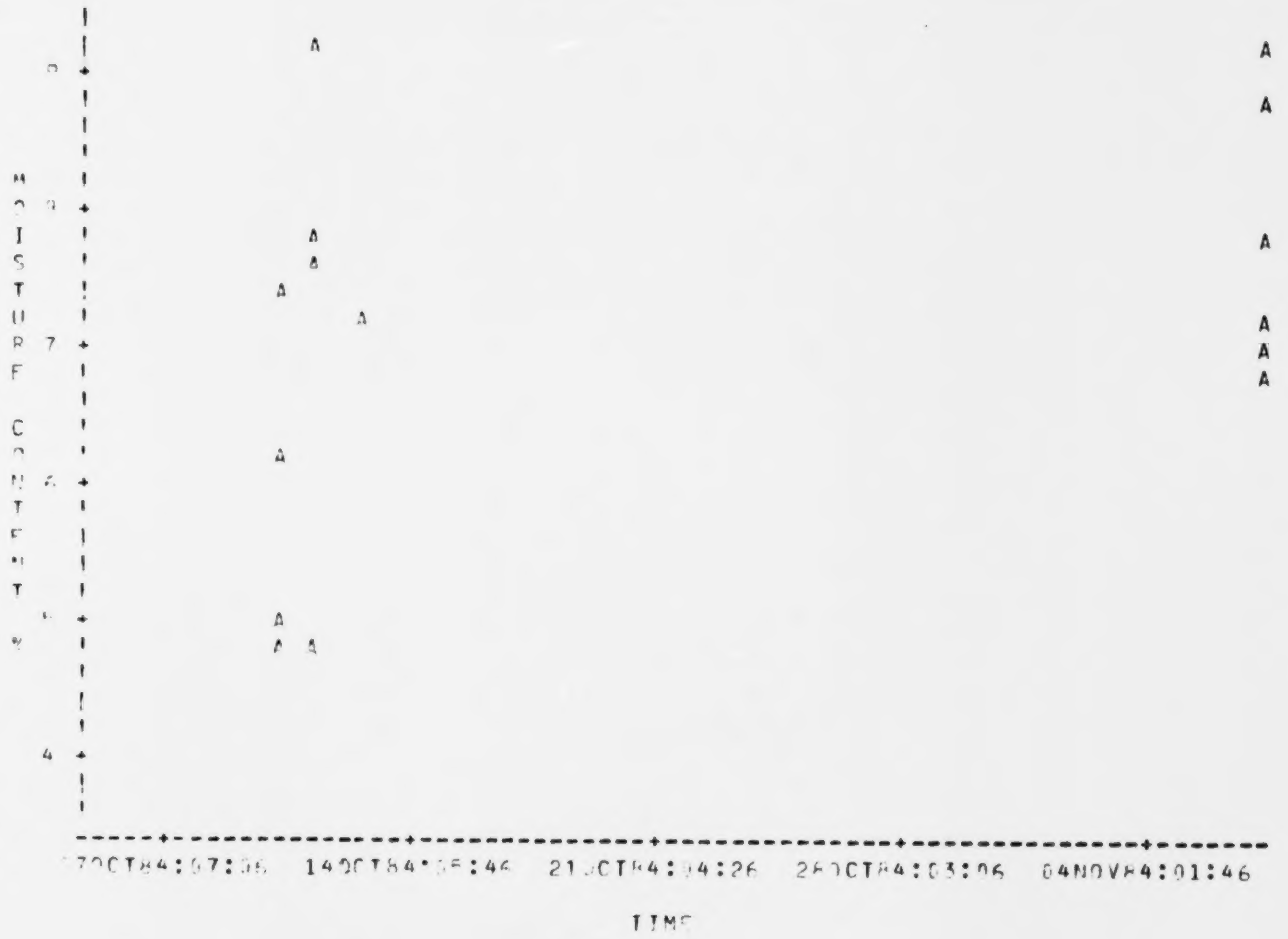

Figure G-3. (Pg. 2).

CHEVRON LANDTREATMENT (EL SEGUNDO)
PLOT=C

PLOT OF WATER*DT LEGEND: A = 1 OBS, B = 2 OBS, ETC.

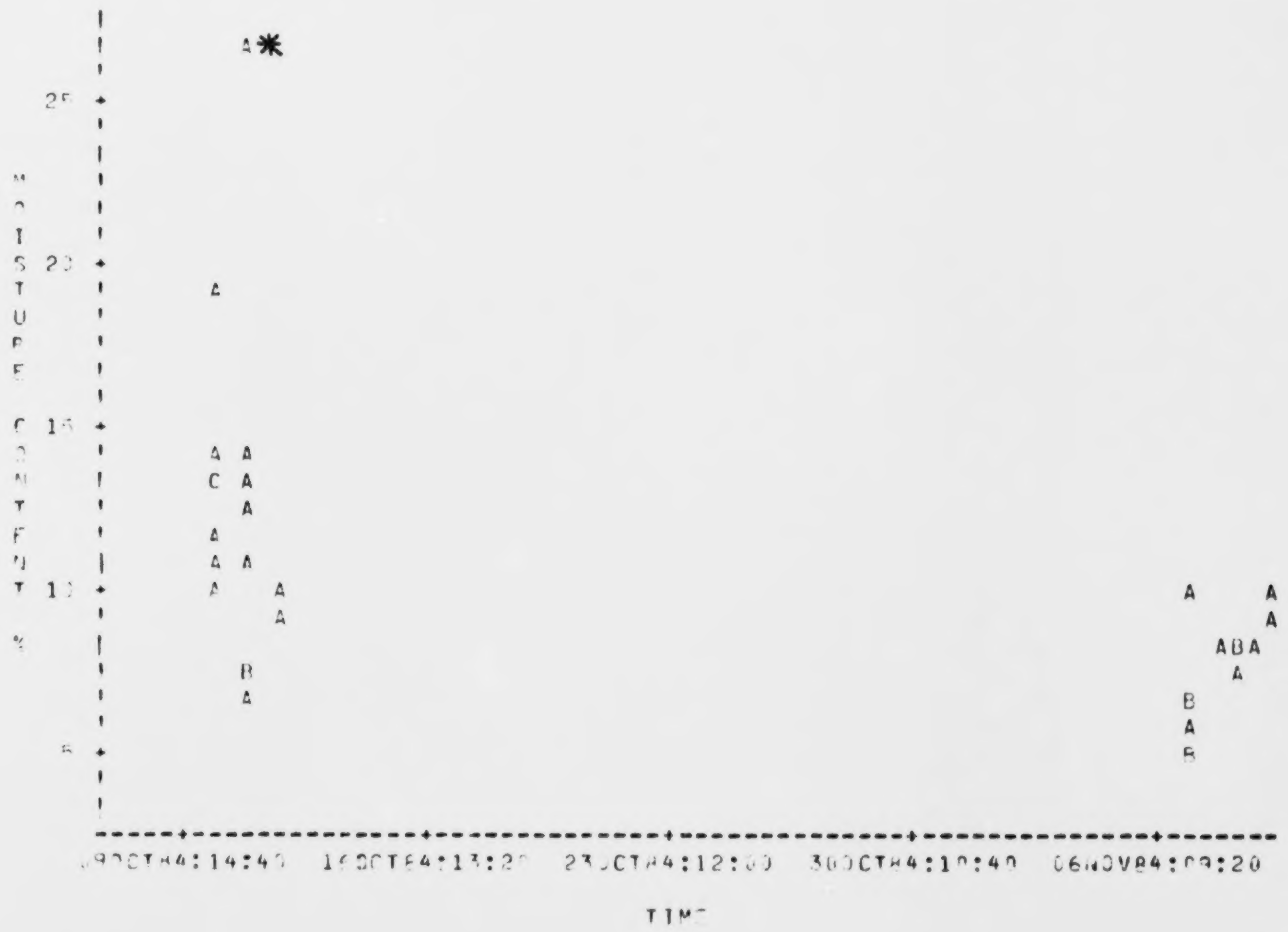

Figure G-3. (Pg. 3).

CHEVRON LANDTREATMENT (EL SEGUNDO)
PLOT=A

PLOT OF OIL*DT   LEGEND: A = 1 OBS, B = 2 OBS, ETC.

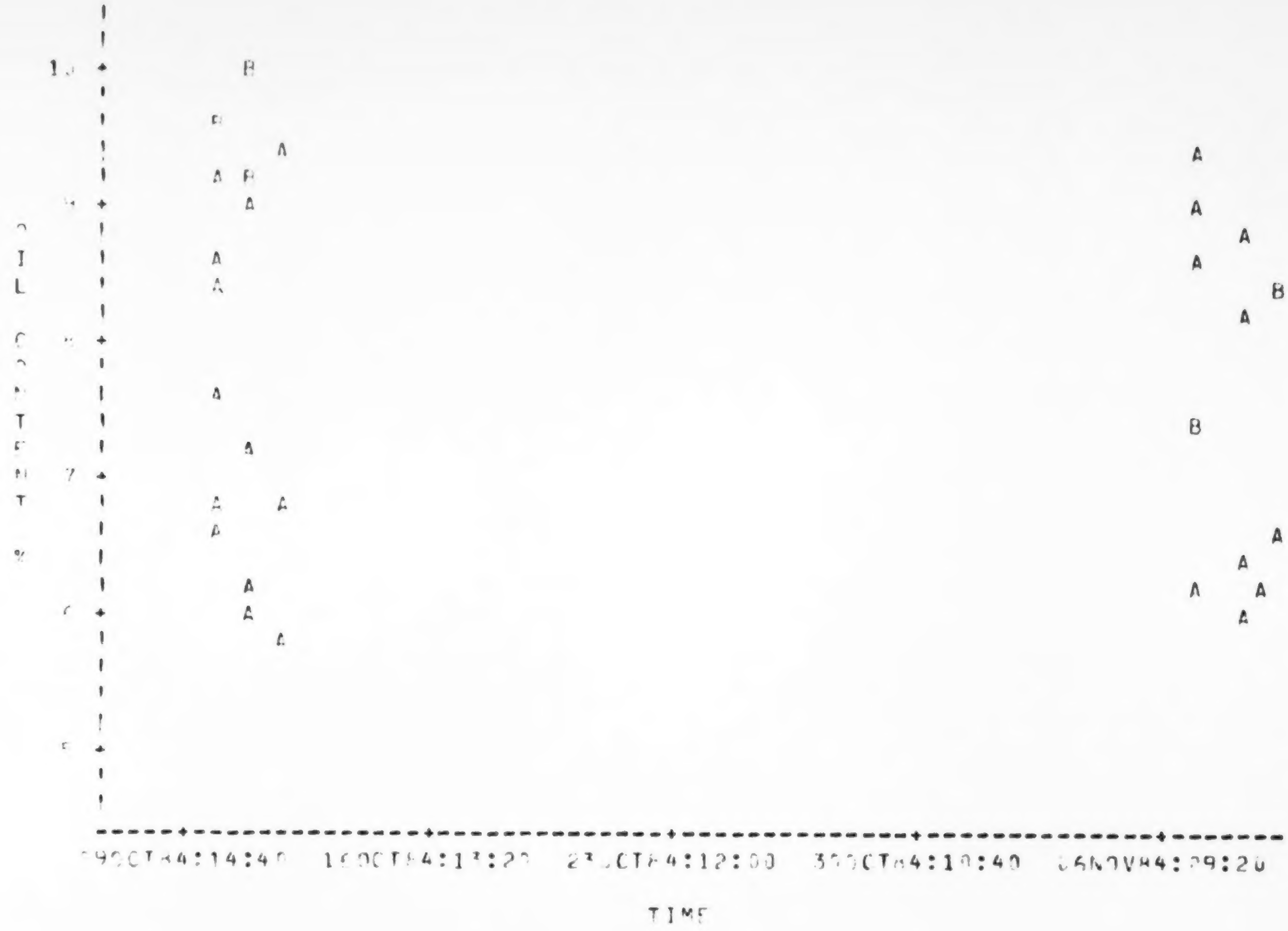

Figure G-4. Plots of soil oil content vs. time.

CHEVRON LANDTREATMENT (EL SEGUNDO)
PLOT=B

PLOT OF OIL*DT   LEGEND: A = 1 OBS, B = 2 OBS, ETC.

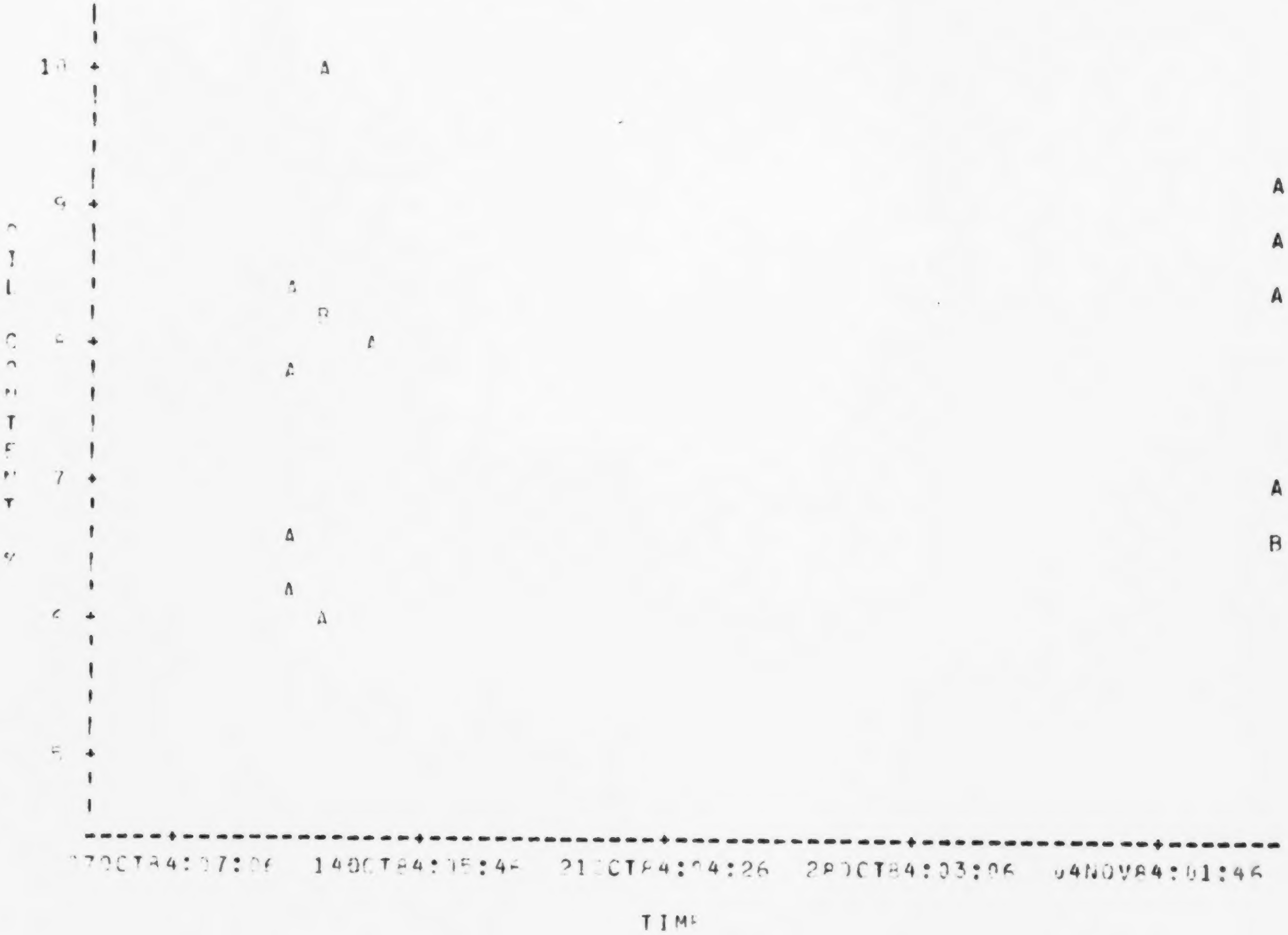

Figure G-4. (Pg. 2).

CHEVRON LANDTREATMENT (EL SEGUNDO)
PLOT=C

PLOT OF OIL*DT   LEGEND: A = 1 OBS, B = 2 OBS, ETC.

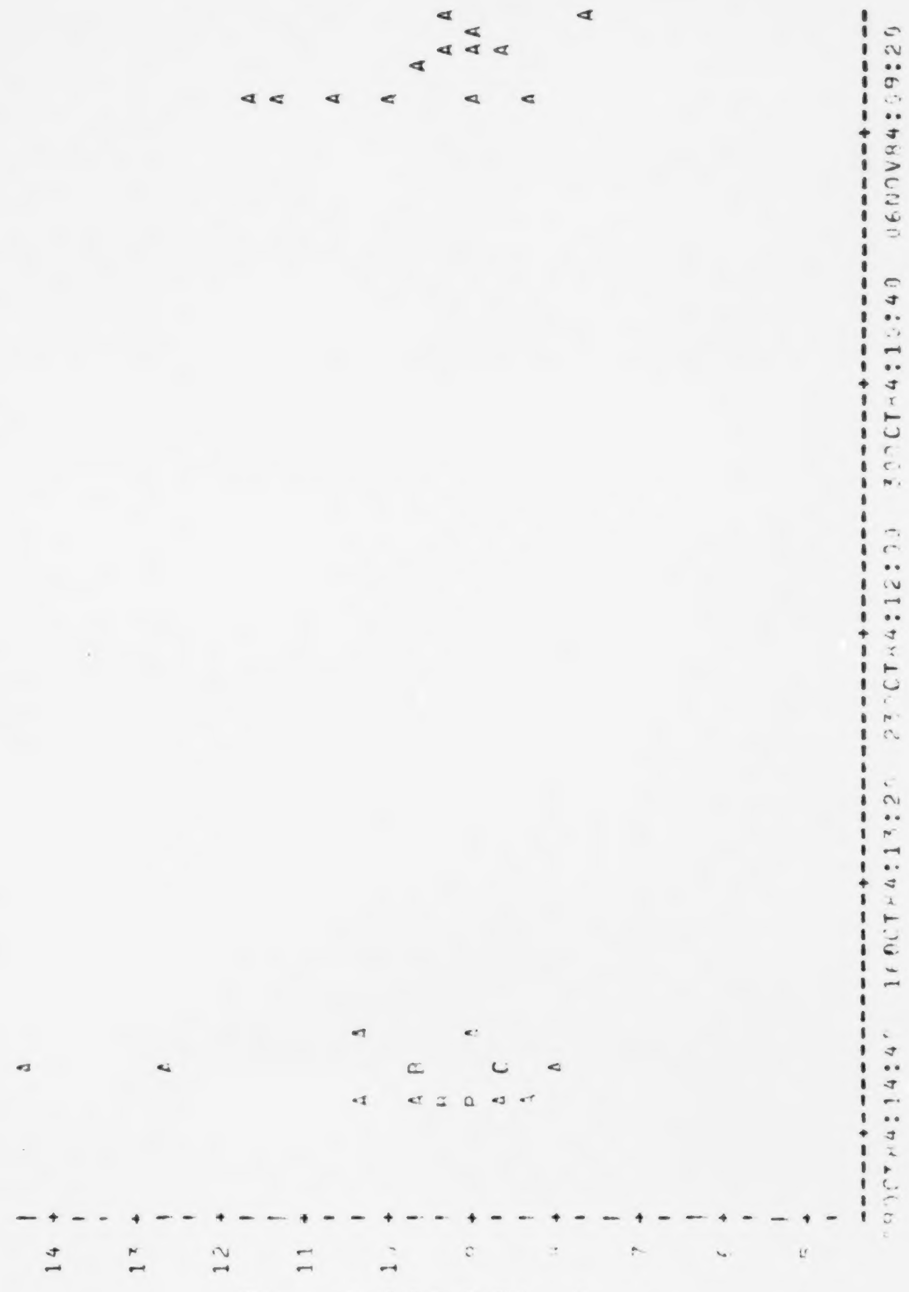

Figure G-4. (Pg. 3).

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CHEVRON LANDTREATMENT (EL SEGUNDO)
PLOT=A   MONTH=OCT

PLOT OF OIL*DT    LEGEND: A = 1 OBS, B = 2 OBS, ETC.
```

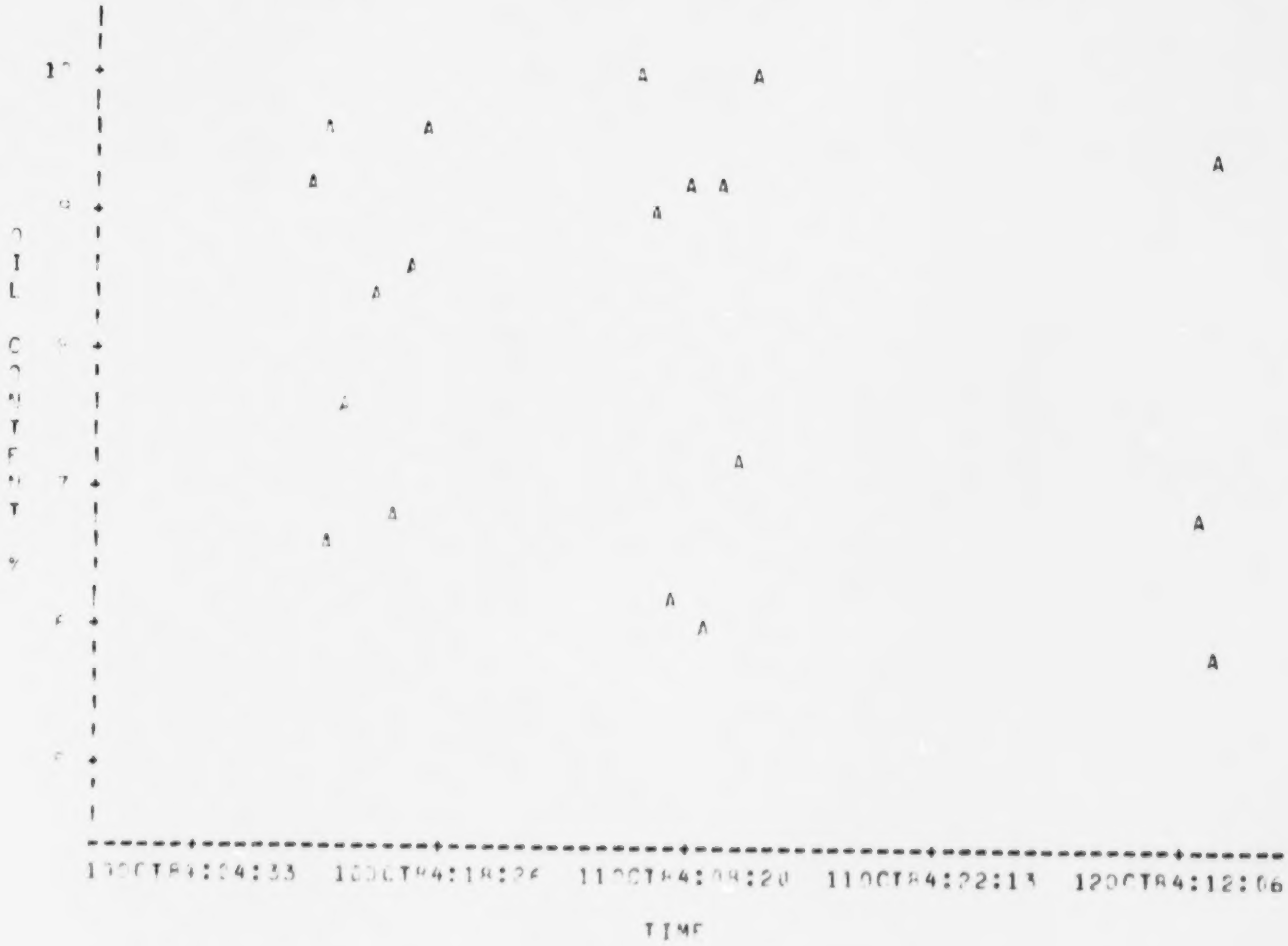

Figure G-4. (Pg. 4).

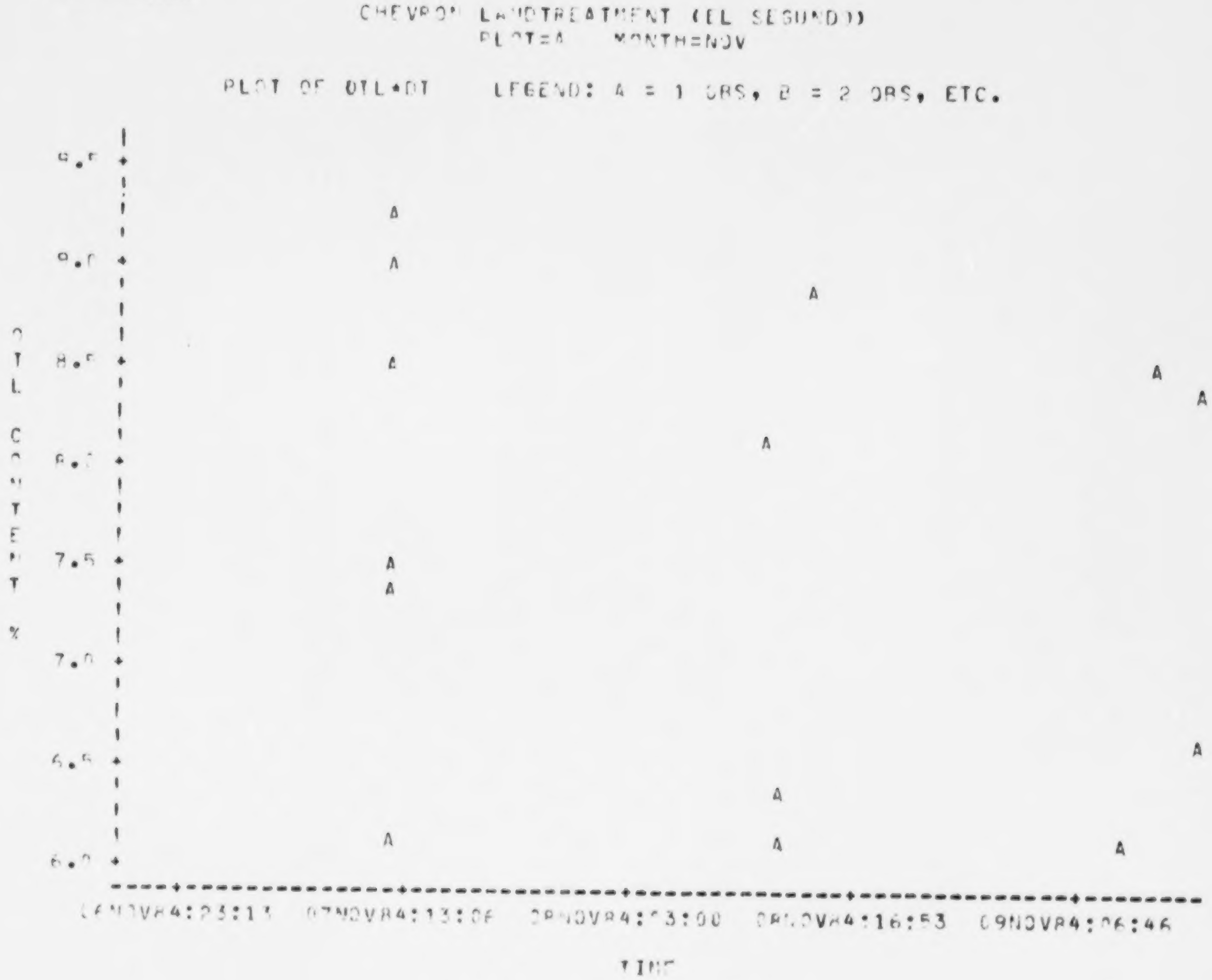

Figure G-4. (Pg. 5).

CHEVRON LANDTREATMENT (EL SEGUNDO))
PLOT=6 MONTH=OCT

PLOT OF OIL*DT LEGEND: A = 1 OBS, B = 2 OBS, ETC.

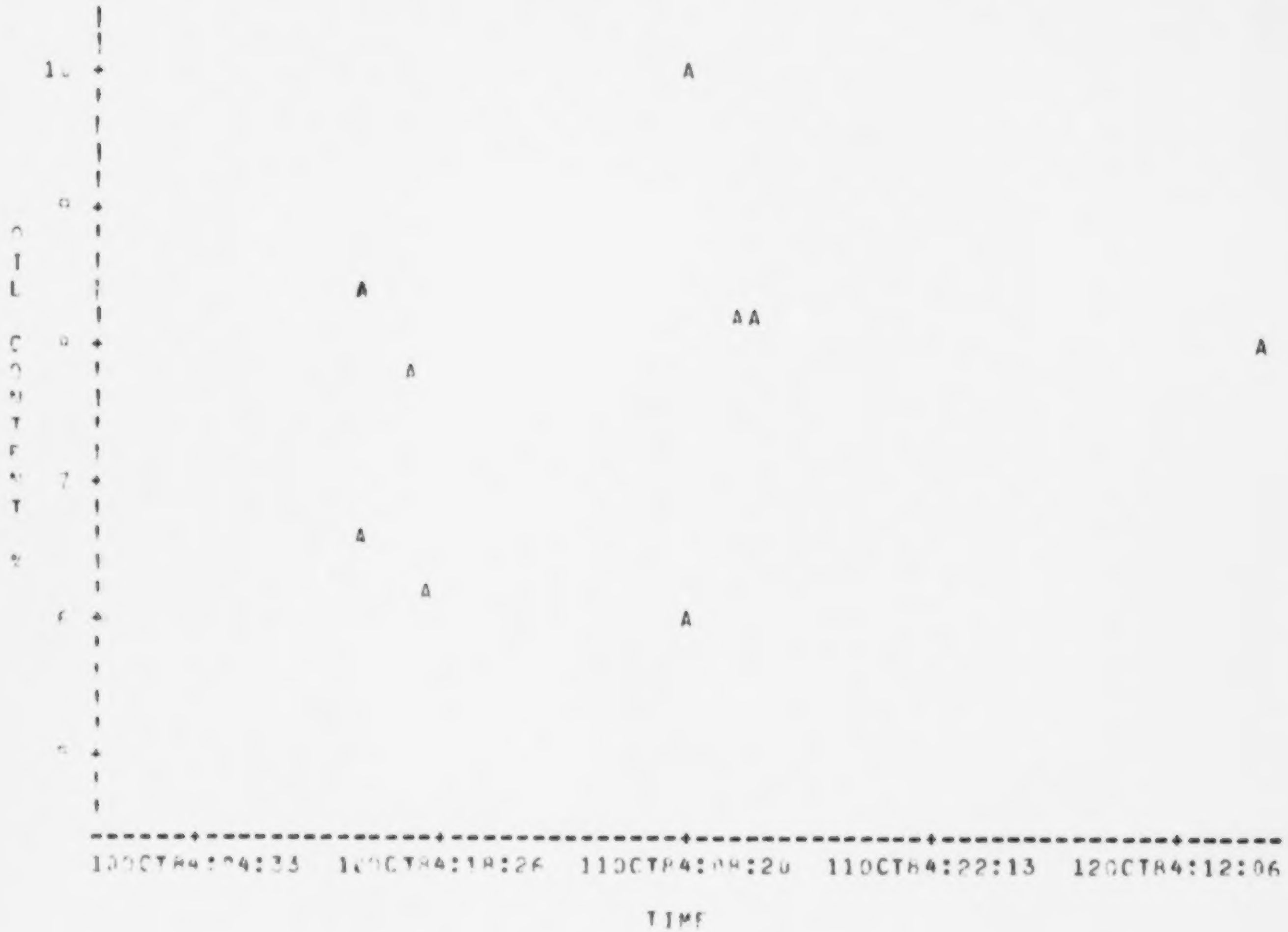

Figure G-4. (Pg. 6).

CHEVRON LANDTREATMENT (EL SEGUNDO)
PLOT=C MONTH=OCT

PLOT OF OIL*DT LEGEND: A = 1 OBS, B = 2 OBS. ETC.

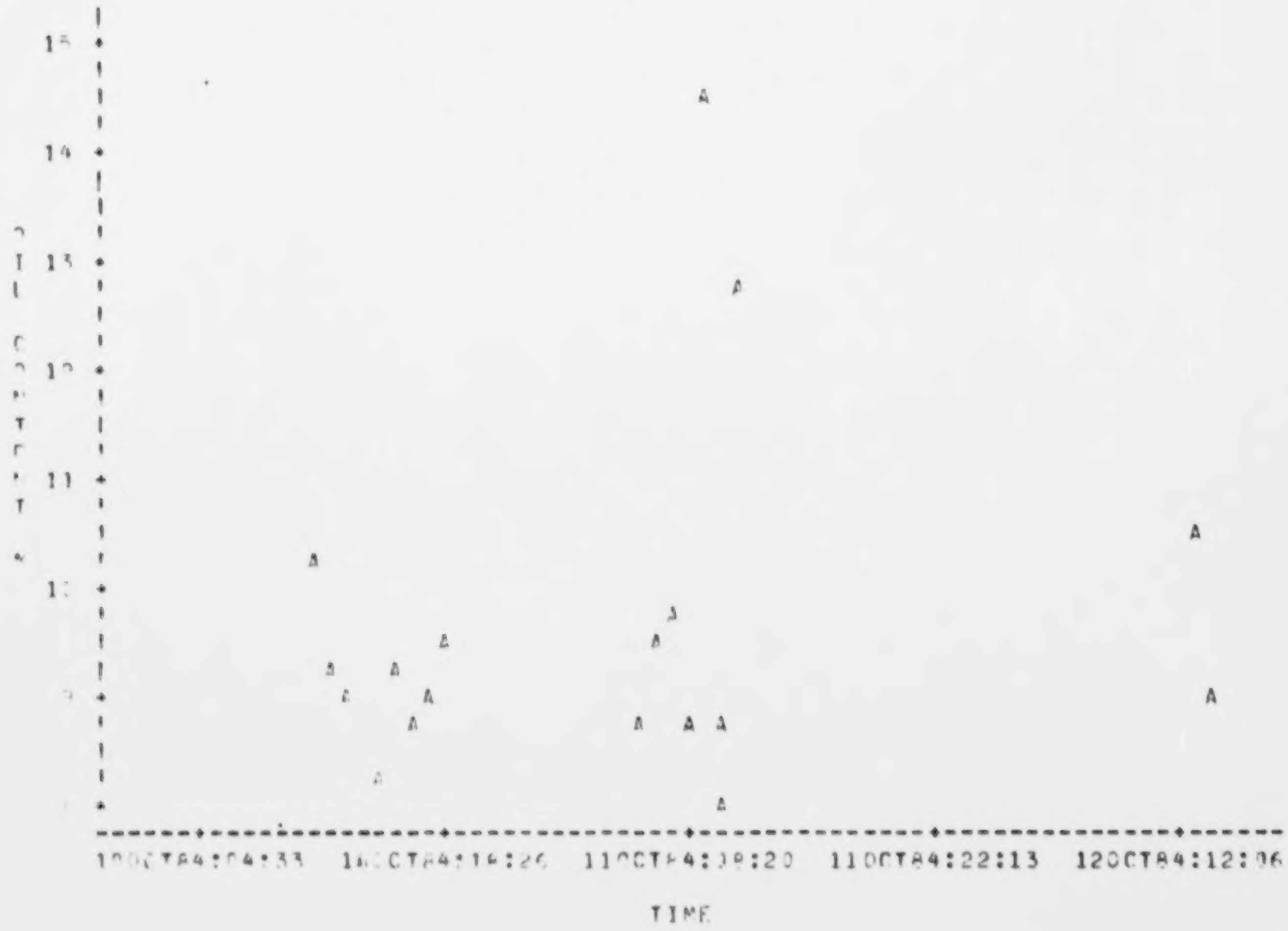

Figure G-4. (Pg. 7).

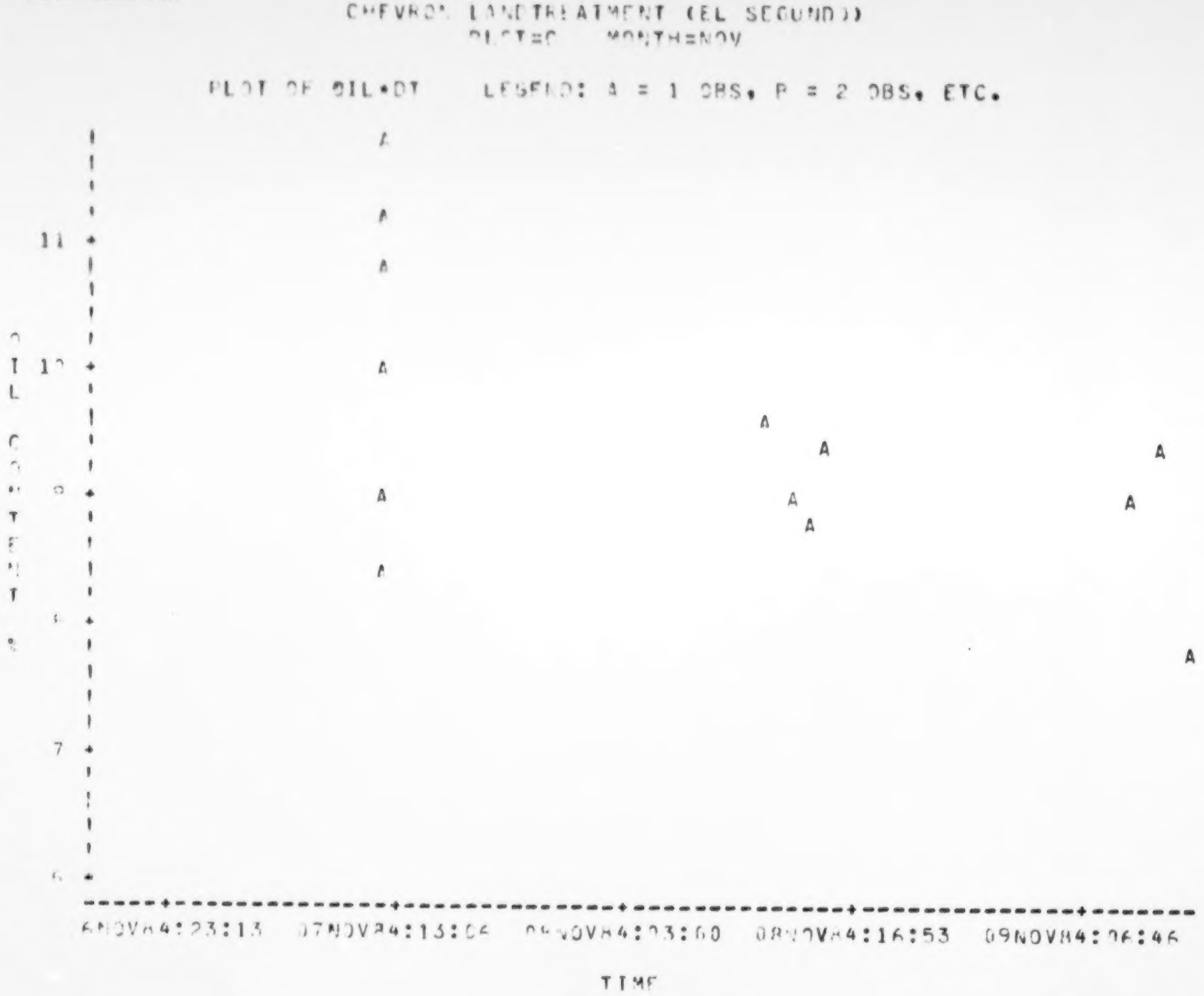

Figure G-4. (Pg. 8).

APPENDIX H

METHOD OF CALCULATING ESTIMATED TOTAL EMISSIONS

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APPENDIX H

This appendix documents the approach used in calculating the estimated total emissions from the landfarm plots in El Segundo. Identical procedures were followed for calculating total hydrocarbon emissions and for total emissions of individual compounds.

Three sampling plots of 423 m^2 each were surveyed and each plot divided into 21 equal area grids. Waste was applied on the surface of one plot, beneath the surface at a second plot, and the third plot served as a background plot (no waste applied). Emission rate measurements were made during three one-week periods over a five-week span. Typically, each of the plots with applied waste were sampled eight times per day and the background plot four times per day. Grids to be sampled were selected at random for each plot. Several times during each week, all the plots were tilled. On such days, the sampling load was divided so that one-half the data were collected before tilling occurred and one-half after tilling was completed. Also once during each of the first two sampling weeks, sampling was initiated prior to dawn to assess nighttime emission rates for all of the plots. In order to estimate the total emissions, the five-week test period was divided into three emission periods: nighttime emissions, tilling day emissions, and non-tilling day emissions. The following assumptions were made:

- Each day included 12 hours of nighttime (or cool weather) emissions (based on observed temperatures);
- Tilling caused elevated emissions for only six hours (based on experimental results); and
- Emissions for the periods not sampled could be determined by interpolation.

The measured emission rates for each plot were averaged to obtain an emission rate for each 1/2 day (i.e., four sampling points for the plots with applied waste) of sampling. A 1/2 day of sampling is assumed to equal six hours. For each of the first two sampling weeks, nighttime emissions were assumed to be equal to the first 1/2-day average for the days when sampling commenced before dawn during that particular week. On those days, the fourth sampling point for the plots with applied waste was completed before air or soil temperatures rose above nighttime values. For the third sampling week, nighttime emissions were assumed to be equal to the first 1/2-day average from November 8, 1984. On that day, temperatures were cooler than normal and the sky was overcast. Measured emission rates for that period were very low, even in relation to the estimated nighttime emissions for the previous weeks. The following equation was used:

Weekly Nighttime Emissions (kg) = Average Measured Emission Rate
(ug-X_i/m^2-sec) x Plot Area (m^2) x Time (3600 sec/hr)(12 hr/night)
(7 night/week) x Conversion Factor (10^{-9} kg/ug)

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where X_i = total hydrocarbon or the individual compound of interest.

For the tilling day emissions, an equation analogous to the one above was used. The 1/2-day average emission rates used were those measured both before and after tilling. The number of tilling days was based on plant records. The day of application was treated as a non-tilling day. The equation used was:

$$\text{Weekly Tilling Day Emissions (kg)} = \text{Average Measured Emission Rate } (\text{ug-}X_i/\text{m}^2\text{-sec}) \times \text{Plot Area } (\text{m}^2) \times \text{Time } (3600 \text{ sec/hr}) (12 \text{ hr/day})(\#\text{ tilling days/week}) \times \text{Conversion Factor } (10^{-9} \text{ kg/ug})$$

The procedure for the non-tilling days differed from the tilling days only in that the number of non-tilling days per week and in the 1/2-day averages used. The average measured emission rate was determined from all the 1/2-day averages from the non-tilling days with the exception of the first 1/2-day average from the sampling days with early starts. This was omitted because this value was indicative of nighttime emissions, not daytime.

The total emissions in kilograms for each sampling week were calculated for each of the three emission periods; nighttime, tilling days, and non-tilling days. Emissions for the weeks not sampled were determined by interpolation and then the emissions were summed up for each plot for the five-week test period. These values were plotted and also related to the amount of material applied and plotted. An example calculation of the estimation procedure described above is given below.

ATTACHMENT 1

EXAMPLE CALCULATION FOR TOTAL ESTIMATED EMISSIONS FROM PLOT A

The average measured emission rates by plot by half-day used in the following calculations are taken from Table 19, page 68 of the Final Report. These values were typically derived by averaging four individual measurements taken at four distinct sampling points within each plot.

1.0 Nighttime Emissions

Week #	Average Nighttime Emission Rate (ug/m^2-sec)	Estimated Emissions (kg)
1	22.5	2.878
2	14.46	1.849
3	6.41	0.820
4	4.49	0.574
5	2.56	0.327
	Total =	6.45

The numbers in the above table were derived as follows: Nighttime emission rates were assumed to be equal to the first 1/2-day average emission rate for those days when sampling commenced prior to dawn. For Week #1 that was 10-11-84, for Week #3 it was 10-25-84, and for Week #5 it was 11-08-84. The value for Weeks #2 was found by interpolation as shown in Equation 1.

$$\begin{array}{c}\text{Average}\\ \text{Nighttime}\\ \text{Emission}\\ \text{Rate}\\ \text{(ANER)}\end{array} = \frac{\begin{array}{c}\text{ANER}\\ \text{Week \#1}\end{array} + \begin{array}{c}\text{ANER}\\ \text{Week \#3}\end{array}}{2} \qquad \text{(Equation 1)}$$

$$= (22.5 + 6.41)\ ug/m^2\text{-sec}$$

$$= 14.46\ ug/m^2\text{-sec}$$

A similar interpolation of Weeks #3 and #5 yielded 4.49 ug/m^2-sec. The total estimated nighttime emissions for a week are given in Equation 2.

$$\begin{array}{c}\text{Weekly}\\ \text{Nighttime}\\ \text{Emissions}\\ \text{(kg)}\end{array} = \begin{array}{c}\text{Average}\\ \text{Measured}\\ \text{Emission Rate}\\ (ug/m^2\text{-sec})\end{array} \times \begin{array}{c}\text{Plot}\\ \text{Area}\\ (m^2)\end{array} \times \begin{array}{c}\text{Time}\\ \text{(sec/week)}\end{array} \times \begin{array}{c}\text{Conversion}\\ \text{Factor}\\ \text{(kg/ug)}\end{array} \qquad \text{(Equation 2)}$$

For Week #1 this would be:

Week #1
Nighttime
Emissions (kg) = $(22.5\ \text{ug/m}^2\text{-sec})(423\ \text{m}^2)(3600\ \text{sec/hr})(12\ \text{hr/night})(7\ \text{nights/week})(10^{-9}\ \text{kg/ug})$

= 2.88 kg

The values for all five weeks were summed to arrive at the total of 6.45 kg.

2.0 Tilling Day Emissions

Week #	Average Tilling Day Emission Rate (ug/m^2-sec)	Estimated Emissions (kg)
1	97.1	3.549
2	67.1	3.678
3	37.1	2.034
4	21.93	2.004
5	6.76	0.247
		Total = 11.5

The numbers in the above table were derived as follows. The 1/2-day average for both halves of each day when tilling occurred during the test week were themselves averaged as shown below for Week #3.

- Tilling occurred on 10-24-84 and 10-26-84
- Average emission rate = $\dfrac{(8.04 + 49.1 + 21.85 + 71.1)\ \text{ug/m}^2\text{-sec}}{4}$

$= 37.1\ \text{ug/m}^2\text{-sec}$

The total estimated emissions for the week are calculated by Equation 2.

For Week #3 this would be:

Week #3
Tilling Day
Emissions (kg) = $(37.1\ \text{ug/m}^2\text{-sec})(423\ \text{m}^2)(3600\ \text{sec/hr})(12\ \text{hr/day})(3\ \text{days/week})(10^{-9}\ \text{kg/ug})$

= 2.03 kg

Note that the time factor is different than for the nighttime emissions calculations. As explained in the last section, values for Weeks #2 and #4 were found by interpolation and the values for each week were summed to arrive at the total.

3.0 Non-Tilling Day Emissions

Week #	Average Non-Tilling Day Emission Rate (ug/m^2-sec)	Estimated Emissions (kg)
1	100.7	9.197
2	57.85	4.228
3	15.03	1.099
4	9.85	0.360
5	4.68	0.427
		Total = 15.3

The numbers in the above table were derived as follows. The 1/2-day averages from both halves of all non-tilling days were themselves averaged. The first 1/2-day average for the early start day was omitted from this averaging process. For Week #3, the applicable values would be both 1/2-day averages from 10-23-84 and the second 1/2 day of 10-25-84 or:

$$\text{Average Non-Tilling Day Emission Rate} = \frac{(16.6 + 15.0 + 13.5)\ ug/m^2\text{-sec}}{3}$$

$$= 15.03\ ug/m^2\text{-sec}$$

The total estimated emissions for a week are calculated by Equation 2. For Week #3, this would be:

$$\text{Week \#3 Non-Tilling Day Emissions (kg)} = (15.03\ ug/m^2\text{-sec})(423\ m^2)(3600\ sec/hr)(12\ hr/day)(4\ days/week)(10^{-9}\ kg/ug)$$

$$= 1.10\ kg$$

As explained previously, values for Weeks #2 and #4 were found by interpolation and the values for each week were summed to arrive at the total.

4.0 Total Estimated Emissions

The total estimated emissions for Plot A are determined by adding the nighttime emissions, tilling day emissions, and non-tilling day emissions.

Total Estimated Plot A Emissions = (6.45 + 11.5 + 15.3) kg

= 33.3 kg

This is the value reported on page 82 of the Final Report. The plots of total emissions as the % of applied VOC (Figure 23, page 85) and total emissions as the % of applied oil (Figure 24, page 86) required calculation of the VOC or oil loading. A total of 165 barrels of sludge were applied to the two test plots. This works out to be 1.403 x 10^4 kg/plot by the following calculation:

(165 barrels)(158.98 L/barrel)(1000 g/L)(density = 1.07)
= 2.807 x 10^4 kg sludge applied

Divide by two to get 1.403 x 10^4 kg sludge/plot. From Table 7, page 35, the seven analyses of the applied sludge yielded 5976, 16600, 5612, 4150, 5390, 5360, and 11680 ug/g total NMHC. This averages 7824 NMHC or 0.7824% VOC.

(1.403 x 10^4 kg sludge/plot)(0.7824% VOC/sludge) = 110 kg VOC/plot

From Table 8, page 36, the average weight % oil in the sludge was 37.5%. The oil loading was thus:

(1.403 x 10^4 kg sludge/plot)(37.5% oil in sludge) = 5260 kg oil/plot

These values served as the denominators when calculating values for Figure 23 and 24.